National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

Canada

UNIVERSITY OF ALBERTA

Wood Quality and Forest Management in British Columbia

by

Sarah Marguerite Jennings

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

IN

FOREST ECONOMICS

DEPARTMENT OF RURAL ECONOMY

EDMONTON, ALBERTA

FALL, 1993

National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-88177-1

Canada

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Sarah Marguerite Jennings

TITLE OF THESIS: Wood Quality and Forest Management in British Columbia

DEGREE: Doctor of Philosophy

YEAR THIS DEGREE GRANTED: 1993

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form without the author's prior written permission.

Sarah M. Jennings

Oct. 12, 1993

Economics Department
University of Tasmania
Hobart, Australia

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Wood Quality and Forest Management in British Columbia submitted by Sarah Marguerite Jennings in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Forest Economics.

Oct. 5, 1993

Dr. M. B. Percy

Dr. W. L. Adamowicz

Dr. J. Louviere

Dr. J. S. Veeman

Dr. M. L. Lerohl

Dr. W. F. Hyde

Abstract

Wood quality is increasingly being acknowledged as an important consideration in decisions regarding forest investment and management. Many important growth parameters can now be manipulated to biologically engineer wood embodying specific characteristics. These same characteristics are an important determinant of end-use product yield, quality and cost. Public and private forest owners make substantial commitments of resources to forest research and management activities. These investments should be evaluated in terms of both their economic and their physical consequences, where assessment of economic return reflects the influence of both resource quality and volume.

Broadening the emphasis of forest investment analysis to encompass wood quality considerations requires that biological growth and treatment/response functions, and economic value functions be re-specified in terms of wood characteristics. Although characteristic level analysis is widespread in economics a general paucity of market based data, coupled with the unusually long production period involved in forestry render traditional empirical approaches unsuitable.

This thesis suggests a new method of revealing information about the structure of characteristic markets. This approach preserves the 'economic explanation' which underpins traditional implicit market theory, while employing the empirical survey methods of conjoint analysis. The main empirical component of this thesis involves applying this approach to the study of future wood characteristic markets in Coastal British Columbia. In particular, the judgements of a sample of experts about the expected value of designed experimental multi-characteristic profiles were used to estimate individual level marginal bid surfaces for characteristics. Multi-characteristic judgement responses were also used to characterize aggregate responses to future crop profiles and to estimate a set of numerically scaled and testable crop planning objective weights.

The empirical findings of this thesis are related to current Provincial forest management, silvicultural and genetic improvement policies. The advantages and disadvantages of using data revealed in experimental markets to investigate future implicit characteristic markets are discussed and directions for further research are indicated.

Acknowledgments

Many people deserve thanks for the part they have played in helping me prepare this thesis. I am grateful to them all. I am particularly appreciative of the financial support provided by the Forest Economics and Policy Unit (FEPA) and for the considered input of the many, busy people who responded to the survey. I am also indebted to my supervisors and to the members of my examination committee for their useful comments and encouragement. My very special thanks go to my good friend and supervisor, Mike Percy, without whose good humour and persistence this thesis would never have been completed.

Table of Contents

Chapter		Page
I.	Introduction	1
II.	Implicit Characteristic Markets and Hedonic Prices	11
III.	Conjoint Analysis: Price-Compensated Profit Surfaces and Scenario Conditioned Judgements	25
IV.	Review of Wood Quality Literature	45
V.	Future Wood Quality Survey - Survey Description	58
VI.	Future Wood Quality Survey - Results and Analysis	70
VII.	Discussion of Results and Conclusions	99
	References	116
	Appendix I	122
	Appendix II	143
	Appendix III	146

List of Tables

Table — Page

VI.1.1. Summary Measures of Consensus by Question 74

VI.1.2. Summary of Individual Main-Effects Conjoint Equation Estimation 79

VI.1.3. Marginal Characteristic Bids for Respondent #58 80

VI.1.4. Summary of Individual Marginal Characteristic Bids 81

VI.2.1. Regression of First and Second Moments of Responses on Characteristics 86

VI.2.2. Regression of CCDFBETA(.44,α,β) on Characteristics 89

VI.2.3. Contribution of Characteristic Levels to Proportion of Favourable Ratings 90

VI.3.1. Timber Quality Objective Scale Values Estimated from Most/Least Choice Data 93

VI.3.2. Distribution of Level-Two Crop Planning Objective Rankings 95

VI.3.3. Timber Crop Planning Objective Scale Values Estimated from Most/Least Choice Data 96

VI.3.4. Timber Quality Objective Scale Values Estimated for Expert Subgroups 97

List of Figures

Figure		Page
II.1	Market Equilibrium Determined by Consumer and Producer Indifference Surfaces	19
II.2	Market Equilibrium Determined by Characteristic Demand and Supply Functions	19
V.1.	Summary of Respondents' Occupational Profiles	62
V.2.	Assumed Hierarchy of Commercial Objectives for Provincial Crop Planning	64
V.3.	A Representative Comparison Set for Largest Difference Experiment	64
V.4.	Timber Crop Characteristics used in Section 4 Experiment Design	67
VI.2.1.	Actual and Predicted Response Distributions for Selected Profiles	83
VI.2.2.	Predicted Beta Distribution for Profile #3 and Selected Improvements	87
VI.3.1.	Level-Three Objective Priority Groupings	94
VI.3.2.	Level-Two Objective Priority Groupings	96

Chapter I: Introduction

Timber processors in Canada have probably always been aware of the effect of wood quality on product recovery, grade and profitability; and forest managers and scientists have long acknowledged the link between the quality of wood produced and various site, silvicultural and genetic factors. However, widespread recognition of wood quality as a key determinant of forest sector competitiveness and as an important issue in timber crop planning is recent. Forest research, management and planning agendas have traditionally been dominated by questions regarding timber volume rather than quality. Substantial commitments of physical, financial and intellectual resources have been made to assessing standing timber inventories, to measuring wood flows, to predicting the size and geographical distribution of future wood resources and to enhancing the capacity of natural forest systems to accumulate volume. Comparable commitments of resources to the study and enhancement of wood quality are only now being contemplated.

The changing emphasis which forest managers have placed on timber volume and quality considerations mirror broad historical shifts which have occurred in the nature of forestry and the forest resource. Canada's forest sector developed around the utilization of a plentiful, high quality, unmanaged natural timber resource. For the most part, the forest resource was viewed as being, and utilized as if it were, limitless. The perceived magnitude of the resource meant that the need to actively husband the forest was not recognized and natural processes were largely relied upon to regenerate harvested areas.

Eventually, however, the combined force of increasing demands for both timber and non-timber forest outputs, the failure of natural processes to adequately restock previously harvested areas, increasing environmental restrictions on timber production and the 'falldown' associated

with a growing reliance on regrowth forests[1] prompted concern about future timber availability and precipitated a growing interest in the links between intensified timber management and accelerated growth rates[2].

Changes in the volume of timber available from Canada's forests have been paralleled by changes in the quality of the harvest. At first, only the best trees of select species were used. In British Columbia utilization of the large, slowly-grown timbers (with which the Province was so well endowed and upon which markets have traditionally placed high premiums) was an important factor in enabling the Province to maintain a prominent position in world forest product markets. Over time, however, industry was forced to use smaller, less perfect trees taken from both oldgrowth stands and stands of natural regrowth, and of species formerly regarded as waste. The slow growth rates and high stocking densities experienced in early regrowth stands means that they share many of the oldgrowth resources historically desirable, and valued,

---

[1] The reduction in timber volume associated with a switch from oldgrowth forests to a regrowth resource is known as 'falldown'. Falldown occurs because forests are harvested at a younger age. For example, one hectare of 300-year-old Coastal forest provides about 750 cubic metres of wood - the same area harvested at 80 years may only yield 500 cubic metres (British Columbia, Ministry of Forests, 1983).

[2] For example, Nilsson (1985) suggested that the Annual Allowable Cut (AAC) for British Columbia in the year 2000 would be approximately 67 million cubic metres - some 8 million cubic metres less than official estimates. Nilsson argues that "this falldown in AAC is a result of numerous factors: land is being withdrawn from the productive forest landbase for non-industrial uses and as a result of fire and insects; supplies of oldgrowth timber on economically operable areas are nearly exhausted; yields on second growth stands will be less than from oldgrowth timber; there are gaps in the age-class distribution". More recently, based upon assumptions about harvests, exports and industrial capacity which reflect "a conservative view of what is most likely to happen", Lonnstedt et. al (1990) predicted a total annual sawlog deficit of between 11 and 12 million cubic metres, and a chip deficit of about 7.7 million cubic metres per year to the year 2010. Both studies acknowledge the potential contribution of intensified management to meet anticipated shortfalls in supply.

characteristics[3] (Barbour and Kellog, undated). However, at the time of harvest this resource consists of smaller trees each containing a larger proportion of its volume as juvenile wood[4].

Growing pressure to produce a large volume of wood at a faster rate will further impact the quality of the wood supply. In Canada, silvicultural techniques intended to increase diameter growth are likely to increase the proportion of juvenile wood in the lower stem and produce wide growth rings, a higher incidence of knots, and more severe taper; changes which imply a reduced suitability of the wood for a wide range of traditional forest products (Barbour and Kellog, undated). Forest growing regions such as New Zealand and the southern United States, which already have a full rotation or more of intensively cultivated resource behind them, have recorded quite dramatic changes in wood properties. For example, New Zealand's 'new crop' of intensively tended plantation-grown Pinus Radiata consists of smaller pieces, contains a higher proportion of sapwood and pruned logs, has larger branches and internodes, and is more variable in quality than was either of the indigenous or early, untended plantation resources (Sutton, 1987).

There is no question that forest managers have the ability to intentionally and dramatically influence both the volume and quality of wood which is produced. Although the initial choice of a site upon which to establish a forest crop defines biomass potential via the influences of

---

[3] 'Characteristics' are properties or attributes of goods (or services). Wood, for example, has characteristics such as specific gravity, fibre length and percentage latewood. Therefore, 'goods' may be thought of as aggregates of characteristics tied together out of technical necessity, convenience or for economic imperatives.

[4] Juvenile wood refers to "that portion of the xylem surrounding the pith in a cylindrical column whose cells have not yet fully matured" (Smith and Briggs, 1985). Juvenile wood occurs in all trees. Its extent depends primarily on ring age. Consequently, trees which achieve merchantable dimension at a young age will contain a high proportion of juvenile wood. Juvenile wood generally has lower tensile strength and specific gravity, shorter fibre lengths, greater longitudinal shrinkage, higher lignin and hemicellulose content and may have a greater tendency to spiral grain than does mature wood (Smith and Briggs, 1985).

rainfall, temperature, light and soils, forest productivity and stand quality can be strongly influenced by silvicultural practices. While some environmental factors cannot be manipulated, others can be altered. Irrigation and fertilization can affect both yield and wood properties by temporarily augmenting site resources and site preparation can provide better growing conditions for trees. Planting and artificial seeding can help close the gap between potential and actual yields by promoting regular stocking, preserving good site occupancy and reducing the incidence of stress-induced defects.

Manipulation of the growing stock directly can also enhance productivity. Juvenile spacing and thinning concentrate the growth potential of site resources on fewer stems while pruning removes branches and encourages the production of knot-free clearwood. In addition, resources devoted to protecting a stand (from fire, pest, disease and encroachment by competing species) influence the probability of anticipated yields and quality characteristics being realised and can reduce the incidence of physical damage and stress-induced defects in stands. The length of time over which trees are allowed to grow influences many size related characteristics and the proportion of juvenile wood in the harvest.

Finally, genetic improvement provides an additional source of control over the nature of future forest crops. "Forest trees are among the more genetically variable organisms yet studied. This variation provides the opportunity to supplement other forestry practices aimed at increasing the quantity and quality of forest products" (Lester, undated). Accumulated evidence suggests that genetic variation is present for many wood, stem and crop characteristics, apart from quantity, which may prove to be of economic importance. For example, fibre length, fibril angle, wood density, bole taper, straightness and branching characteristics can be modified through appropriate selection. In addition, uniformity within traits and the rate of change in properties to maturity are both heritable (Bendtsen, 1978). The application of genetic principles

to trees, known as tree breeding, traditionally involves a sequence of selection, testing and seed orchard development activities aimed at identifying and developing the potential of naturally occurring genetic variation. More recently, rapid advances in biological research suggest that tree cloning technologies will facilitate even more rapid genetic progress. One tree-cloning technology, somatic embryo genesis, enables tree breeders to genetically program parent stock, thereby offering the scope to introduce special characteristics which lie outside the range of existing genetic variation (Thorpe, undated)[5].

The extent to which forest productivity is increased and wood quality modified depends upon the way in which resources are allocated to forest management activity. In British Columbia, decisions which govern the level and nature of this resource allocation are principally in the hands of the government. Through its ownership of over 90 percent of forest land, provincial policy effectively dictates the pattern of forest management, utilization and protection. The federal government also exerts influence directly via its involvement in federal-provincial forestry agreements and indirectly through its control of tax and trade policies (Lonnstedt et al., 1990).

Current silvicultural programs in British Columbia involve substantial resource commitments for long periods of time. The Ministry of Forests makes expenditures related to silviculture of about $250 million per year (British Columbia, Ministry of Forests, 1989). This includes the cost of basic silvicultural activities (such as surveys, site preparation, planting, brushing and spacing), incremental silviculture (such as fertilizing and the rehabilitation of the backlog of insufficiently restocked forest land) and the operation of nursery and seed operations.

---

[5] For example, using somatic embryo genesis, white spruce embryos can be injected with a gene that produces a natural herbicide that kills spruce budworm. Similarly, other researchers in British Columbia use rooted cutting technologies to by-pass the problems associated with the poor natural seeding characteristics of a popular wood, yellow cedar (Globe and Mail, 1989).

The Ministry's research, forest protection and fire suppression budgets amount to further resource commitments of about $75 million per year. The Province's private sector also commits substantial amounts of resources to forest management and related research.

It is clear that the desirability of these investments must be evaluated in terms of their economic, as well as their physical, consequences. Techniques available for identifying socially efficient levels and patterns of investment in forest management are becoming increasingly sophisticated. For example, stand level models simulate both biological and financial responses to various patterns of management and use common programming algorithms to solve for wealth maximizing forest tending strategies. Ideally, these models should capture the effect of particular stand and tree characteristics on value. However, models invariably focus on wood volume, rather than wood quality space. Consequently, they tend to favour forestry programs and management regimes which produce large volumes of fibre, quickly.

Failure to account for the effect of resource management expenditures on resource quality may prove costly, as bequeathing large volumes of wood of an inappropriate quality to timber processors may impair the Province's ability to compete successfully in future forest product markets. Although subsequent rotations can incorporate lessons learnt from early management experience and technological solutions to utilization problems can often be found expost, it is important that current policies and investment decisions reflect our best knowledge about the expected effects of resource quality on competitive potential.

Experience elsewhere with managed regrowth stands highlights the potential cost of ignoring future utilization requirements. Cubbage and Harris (1986) estimate that the high juvenile wood content of plantation-grown southern pine in the United States may have cost the industry between US$65-135 million per year in terms of reduced lumber yields and significantly more in terms of lost market share. Early investments in plantations of the exotic Pinus

roxburghii in South Africa, although achieving high growth rates, failed due to utilization problems resulting from a high incidence of cross grain in the final crop (Poynton, 1957).

Calls for the development of a 'strategic approach' to timber supply in British Columbia in particular, and Canada in general, are now widespread (Woodbridge, Reed and Associates, 1988; Rotherham and Hatten, undated; Lonnstedt et al., 1990). Lonnstedt et al. identify the lack of strategic thinking amongst both government agencies and the private sector as a constraint upon the British Columbian forest sector's ability to meet the challenges posed by predicted short to medium term fibre deficits. Greater attention to "long term objectives, priorities, action plans and accountability" are required if the implications of the authors' "worst scenarios" are to be avoided.

The need to actively manage the quality of future wood resources within the context of a strategic approach to future wood fibre supply is now well established. Several authors have stressed the need to 'fine-tune' the characteristics of future wood resources to match technical processing requirements so as to stave off competitive threats and/or to penetrate new markets. For example, McKimmy (1986) suggests that the goal of forest management must be "to key the forest to product end-use requirements"[6]. He observes that this requires a knowledge of the economic benefits associated with variations in wood quality which, in turn, requires the identification of the "value functions of the different wood quality traits of different species".

---

[6] This view is not universally held. Some authors have argued that strategic advantage will be created by focusing management efforts on exploiting the biological potential to produce fibre volume, leaving technology to find a way to make use of the material produced. In other words, the focus should be on 'technological' rather than 'biological' engineering (Johnson, 1987). Others argue that sophisticated wood sorting processes and the ability to combine a variety of wood and non-wood materials into end products will enable characteristics to be 're-bundled' outside the forest. Neither perspective denies the importance of wood quality. If the former is correct, then wood characteristics associated with high end-use flexibility will, exante, be prized. In the latter case, wood embodying characteristics which lend themselves to being un- and re-tied will be desirable.

This implies that wood characteristic values, rather than wood values, should be used to assess the return to investments in the growing stock. In addition, broadening the emphasis of forest investment analysis to encompass wood quality considerations involves respecifying growth functions and growth responses to management initiatives in terms of their impact on wood characteristics, as well as volume. While the latter challenge lies with forest silviculturalists, biologists and mensurationalists, the former lies clearly with forest economists.

Like wood prices, wood characteristic prices are determined in markets, by the combined forces of supply and demand. However, two factors make identification of characteristic prices significantly more complex than is the identification of wood prices. First, wood characteristics are not traded directly and therefore, do not command explicit, observable prices. Rather, their prices are implicit in the observed prices and characteristic content of quality differentiated goods. Consequently, characteristic prices must be uncovered and the features of the market in which they are determined reconstructed.

Second, since wood production occurs over an unusually long period current characteristic prices are unlikely to accurately reflect future market valuations. This implies that the effect of technological changes in forest growing and wood processing industries and in the markets in which wood products compete (and in which derived wood characteristic demands are determined) must be accounted for. Similarly, future characteristic prices will reflect changes in the tastes of wood product consumers, the availability and price of substitute products and the suite of legal and institutional considerations which shape wood markets and the behaviour of their participants.

One of the greatest constraints to formally incorporating a consideration of wood quality in forest crop planning models and processes has been an inability to translate expected market changes into terms which are readily understood by forest managers and policymakers

(Rotherham and Hatham, undated). Attempts to formally model or to empirically characterize future wood quality markets are limited and are reviewed in Chapter IV of this thesis. The general purpose of this research is to remedy this shortfall by contributing both to the theoretical definition of wood characteristic markets and to the empirical investigation of the structure of future wood characteristic value functions, or demands, in Coastal British Columbia. Specific research objectives are as follows:

(i) To define an economic model of wood characteristic markets and to identify a way in which empirical estimates of market parameters can be derived.

(ii) To design and conduct an empirical experiment, which draws upon the judgements of a sample of 'experts', to construct forecasts of future wood characteristic and quality requirements in the forest products industry of Coastal British Columbia.

(iii) To identify a hierarchy of commercial forest crop planning objectives and to estimate a set of numerically scaled and testable objective weights.

(iv) To relate the results of (ii) and (iii) to current forest management, silvicultural and genetic improvement policies and practices in Coastal British Columbia and to highlight the implications of this research for strategic crop and fibre planning in the Province.

(v) To discuss the advantages and disadvantages, as experienced in this project, associated with using data revealed in experimental contingent market and judgement tasks to investigate implicit characteristic markets.

The rest of this thesis is organised into seven chapters and a series of appendices. In the

following chapter (Chapter II) the notion of an implicit (or hidden) market in which wood characteristics are traded is developed. The limitations of using data revealed in actual market transactions to analyze this market are identified. In Chapter III the link between implicit market theory and metric conjoint analysis is established and a means of adapting the conventional experimental techniques of conjoint analysis to provide estimates of implicit market parameters is explored. Chapter IV provides a review of the wood quality literature.

In Chapter V the design and implementation of an experiment which integrates the judgements of a sample of experts to form expectations of future wood quality needs is described. The results of this analysis are reported and analysed in Chapter VI. Chapter VII assesses the implications of these results for current Provincial policies and practices and highlights their limitations. Finally, directions for further research are indicated.

Chapter II: Implicit Characteristic Markets and Hedonic Prices

Conventional competitive economic theory begins with the hypothesis of well informed price-taking firms and consumers buying and selling homogeneous commodities at well defined marketplaces. Although rich in insight there are many circumstances in which these assumptions are implausible. In some instances buyers and/or sellers are few in number, while in other markets agents are ill-informed. There are commodities for which no marketplaces exist and there are markets in which heterogeneous units of a commodity are available. In this last instance, consumers and producers must decide both the amount and the quality of the commodities which they wish to purchase and produce. Consequently, the conventional competitive model must be modified to capture the nature of the marketplace and its equilibrium.

Attempts to extend conventional models to account for quality differences range in sophistication from those in which quality is treated as a simple shift parameter in demand and supply functions (Theil, 1952; Houthakker, 1952) to those which are based on an explicit characterization of product differences and a redefinition of the parameter space over which optimizing choices are made (Leffler, 1982; Leland, 1977; White, 1972, 1975). The model described here belongs to the later tradition and is strongly rooted in the twin traditions of hedonics and implicit markets. It therefore owes its origins to the pioneering work of Griliches (1971) and Rosen (1974).

Central to both the hedonic and implicit market approaches to market analysis is the concept of a good as a 'tied bundle' of characteristics and the observation that it is the consumption of these characteristics, and not of the goods per se, that contributes to utility and hence the structure of final demand. In much the same way, it is the characteristics of inputs

which determine their value in production and the structure of factor demands[7]. Moreover, the package of characteristics embodied in a good, be it for final or intermediate consumption, will influence production costs and hence, the supply decisions of profit maximizing firms.

Characteristics are not traded directly and do not command explicit prices. However, observed product prices for quality differentiated goods 'imply' a set of characteristic (or hedonic) prices. It is with respect to these hedonic prices that consumers and producers make locational choices regarding the bundle of characteristics bought and sold. Consequently, economic theory is enriched when characteristics supplement commodities in individuals' utility functions and in firms' cost functions, and as choice variables in optimization problems; and when market equilibria are described as spatial locations in characteristic space. It is the traditional task of hedonic analysis to 'uncover' the implicit market valuations of characteristics from observable market data; it is the task of implicit market analysis to reconstruct the structural parameters of the implicit market in which these valuations are determined. The theory of implicit markets and hedonic prices is developed in the following sections of this chapter. It is then argued, that while providing an appropriate characterization of wood markets, traditional implicit market and hedonic estimation procedures are generally unsuited to analzing wood markets with a view to providing information for the purpose of crop planning.

The demand for input characteristics

Consider the market for a class of differentiated inputs which are completely described

---

[7] Empirical applications of hedonic analysis in consumer goods markets are common and much of the pioneering theoretical work in the field has been couched in terms of these markets. The application of the hedonic concept to production theory, or more specifically to input markets, is less common; and, consequently, the theory is less well developed. The hedonic/implicit market approach was first applied to production inputs in Ladd and Martin (1976).

by a vector of j objectively measured characteristics, $Z = (z_1, z_2,\ldots,z_j)$, where z_i defines the amount of the ith characteristic contained in the input. Inputs are useful only because they contain characteristics and an inputs total contribution to production depends on the amount of the various characteristics it provides. In turn, total production depends on the contribution of all inputs. This means that the production function for the kth output of a multi-product firm which produces y outputs using n different classes of inputs and which buys its inputs and sells its products under conditions of competition, can be expressed as[8],

$$q_k = f_k(x_{1k},..,x_{nk};\ z_{11k},..,z_{j1k},..,z_{1nk},..,z_{jnk}) \tag{2.1}$$

q_k is the quantity of output k and x_{sk} is the quantity of input class s used to produce k. z_{isk} is the quantity of characteristic i embodied in a unit of x_{sk}. Thus, equation (2.1) states that the output of the kth product depends upon the amount of the n inputs used and their quality, where the quality of input s is determined by the amount of the j input characteristics contained in a unit of s. For example, the amount of lumber produced per period might depend on the size, density, ring width, and defect content of wood milled and the volume throughput; and upon the number of man-hours employed and the experience and training level of employees.

Firms will seek to simultaneously select the quality and quantity of inputs which maximise profits, where the profit function is revenues (R) less outlays (O). The profit-maximization problem is to,

$$\max_{X_1,\ldots,X_n,Z_{11},\ldots,Z_{1n},\ldots,Z_{j1},\ldots Z_{jn}} \Pi = \max\ [R(P, X_1,\ldots X_n, Z_{11},..Z_{1n},\ldots,Z_{j1}\ldots Z_{jn}) - O(R, X_1,\ldots X_n)]$$

$$= \max\ [\sum_{k=1}^{y} p_k f_k(x_{1k},\ldots,x_{nk};\ z_{11k},\ldots\ldots z_{jnk}) - \sum_{k=1}^{y}\sum_{s=1}^{n} x_{sk} r_s \tag{2.2}$$

P and R are 1*y and 1*n vectors whose elements, p_k and r_s, represent the prices of output

---

[8] This assumes that the production function for the kth output is independent of the production functions for all other outputs.

input s, respectively. Vectors $X_1,\ldots,X_n$ are of dimension 1*y, the elements of which, x_{sk}, represent the quantity of input s used in the production of output n. $Z_{11},\ldots,Z_{1n}$; $Z_{j1},\ldots Z_{jn}$ are nj 1*y vectors whose elements z_{isk} are the amount of characteristic i present in a unit of input s used in the production of output k.

First-order maximization conditions are obtained by setting the partial derivatives of the profit function with respect to input quantities and input characteristics equal to zero. Evaluating and reexpressing these yields the following k(n + jn) conditions,

$$p_k(\delta f_k/\delta x_{sk}) = r_s \qquad s=1,\ldots,n \text{ and } k=1,\ldots,y \qquad (2.3.1)$$

$$p_k(\delta f_k/\delta z_{isk}) = \delta(x_{sk}r_s)/\delta z_{isk} \qquad i=1,\ldots,j,\ s=1,\ldots,n \text{ and } k=1,\ldots,y \qquad (2.3.2)$$

Equations 2.3.1 and 2.3.2 suggest familiar marginal rules for optimization. More specifically, profit maximization requires that the price of each input be equated to the value of the marginal product (VMP) of the input. Since this must hold for all outputs the ny conditions in equation 2.3.1 imply that all inputs should be hired such that the value of their marginal products are equated across production processes. Similarly, profit maximization requires that, for any output k, the value of the marginal product of each input characteristic be equated to its marginal effect on total outlays. Furthermore, for any output k all n inputs and j characteristics must be hired such that the ratio of their marginal prices equals the inverse of their ratio of marginal products. In other words, the profit maximising firm should hire additional units of input s in the production of output k to the point at which its additional contribution to total product per dollar outlayed is equal to that of all other n-1 inputs and j input characteristics[9].

Since it is the characteristics of an input which contribute to production, df_k/dx_{sk} can be

---

[9] For any output k the conditions in equations 2.3.1 and 2.3.2 require that $(\delta(x_{lk}r_l)/\delta z_{plk})/(\delta f_k/\delta z_{plk}) = (\delta(x_{sk}r_s))/\delta z_{isk}/(\delta f_k/\delta z_{isk}) = r_s/(\delta f_k/\delta x_{sk}) = r_l/(\delta f_k/\delta x_{lk})$, for all $i,p=1,\ldots,j$ and $s,l=1,\ldots,n$.

rewritten as $\sum_{i=1}^{j} (\delta f_k/\delta z_{isk})(\delta z_{isk}/\delta x_{sk})$. Substituting into the first ny first-order conditions gives,

$$p_k \sum_{i=1}^{j} (\delta f_k/\delta z_{isk})(\delta z_{isk}/\delta x_{sk}) = r_s \qquad s=1,\ldots,n \text{ and } k=1,\ldots y \qquad (2.4)$$

$\delta f_k/\delta z_{isk}$ is the marginal physical product of characteristic i used in the production of k. Multiplied by p_k it is the value of the marginal product of i, or the marginal implicit (or hedonic) price of a unit of the ith characteristic. The second term of equation(s) 2.4, $\delta z_{isk}/\delta x_{sk}$, is the marginal yield of characteristic i from input s in the production of k. Equation(s) 2.4, therefore, provide the traditional empirical hypothesis that the observed price of each input is equal to the sum of the marginal implicit prices of characteristics possessed by the input, multiplied by the inputs' marginal yields of these characteristics.

The supply of input characteristics

Now consider a competitive firm producing n goods which are inputs to other firms. The firm must decide both the quantity of various classes of inputs to produce $(q_1,\ldots,q_n)$ and the quality of these inputs where the quality of input s is again reflected by the amount of characteristics 1 to j embedded in a unit of s (i.e, $z_{1s},\ldots,z_{js}$). Assuming profit maximizing behaviour a firm will seek to solve the following problem,

$$\max_{Q;Z_1,\ldots,Z_j} \Pi = \max[R(Q,R) - O(Q,Z_1,\ldots,Z_j)]$$

$$\max \sum_{s=1}^{n} q_s r_s(z_{1s},\ldots,z_{js}) - C(Q, z_{11},\ldots z_{1n},\ldots,z_{j1},\ldots,z_{jn}) \qquad (2.5)$$

where Q is a 1*n vector whose elements q_s represent the quantity of product s produced and C is the firms' total cost function. Hence total costs are dictated by both the quantities of the n products produced and the quality of these products. Vectors $Z_1,\ldots,Z_j$ are 1*n vectors the elements of which, z_{is}, denotes the amount of the ith characteristic in a unit of product s and R

is as defined previously.

First-order conditions for an optimum are derived by setting the derivatives of equation 2.5 with respect to the n+nj choice variables equal to zero and rearranging. Optimal production choices require that

$$\delta C/\delta q_s = r_s \qquad s = 1,\ldots,n \tag{2.6.1}$$

$$\delta C/\delta z_{is} = q_s(\delta r_s/\delta z_{is}) \qquad s = 1,\ldots,n \text{ and } i = 1,\ldots,j \tag{2.6.2}$$

The first n conditions suggest that each input should be produced up to the point at which unit revenue (r_s) equals marginal production cost, evaluated at the optimum bundle of characteristics. Furthermore, the optimum bundle of characteristics in a unit of product s is dictated by the j conditions in equation 2.6.2 which state that the additional revenue obtainable by increasing the content of each of the j characteristics must equal the associated marginal cost of production.

Since the characteristics of a product determine production costs the function of a function rule can be used to reexpress $\delta C/\delta q_s$ as $\Sigma\ (dC/dz_{is})(dz_{is}/dq_s)$. Substituting into the first n first-order conditions of equation 2.6.1 gives,

$$\sum_{i=1}^{j} (\delta C/\delta z_{is})(\delta z_{is}/\delta q_s) = r_s \qquad s=1,\ldots,n \tag{2.7}$$

$\delta C/\delta z_{is}$ is the marginal cost of embedding characteristic i in product s and can be thought of as the implicit (or hedonic) value of the characteristic as evaluated from the producers perspective. The second term, $\delta z_{is}/\delta q_s$, is the marginal physical yield of characteristic i from product q_s. Therefore, equation 2.7 reproduces the hypothesis stated in equation 2.4; namely, that the observed price of each quality differentiated product is equal to the sum of the marginal implicit values of characteristics possessed by the product, multiplied by the marginal yields of these characteristics.

The market for input characteristics

The fundamental spatial context of the market in which input characteristics are traded is highlighted by following the lead of Rosen (1974). From equation 2.2 a representative input buyers profit function for a single input and output can be written as

$$\Pi_{x^*}(z_1,\ldots,z_j,\ r,p,\alpha) \tag{2.8}$$

where x^* is the optimal quantity of input x and α represents the set of underlying production function parameters. Define a value, or bid, function $\psi_{x^*}(z_1,\ldots,z_j,\ \pi,p,\alpha)$ such that

$$\Pi_{x^*}(pf(x^*,z_1,\ldots,z_j) - \psi_{x^*}x^*) = \pi$$

$$\text{and,}\quad p(\delta f(x^*,z_1,\ldots,z_j)/\delta x_*) = \psi_x^* \tag{2.9}$$

Hence, ψ_{x^*} represents the amount an input purchaser is willing to pay for different values of the vector $z_1,\ldots,z_j$, for particular levels of profit and output price, given the technology α. The function ψ_{x^*} defines a family of indifference surfaces relating characteristics, z_i, to maximum money bids and $\delta\psi_{x^*}/\delta z_i$ reflects the demand price for an additional unit of z_i. Thus $\{\delta\psi_{x^*}/\delta z_i\}$, $i=1,\ldots,j$, are a set of profit-compensated derived demand functions for the characteristics z_i. Provided Π_{x^*} is strictly concave, ψ_{x^*} will be increasing in z_i at a decreasing rate (Rosen 1974).

Now consider equation 2.5 which defines the profit function for a representative input supplier. This can be expressed as $\Pi_{q^*}(z_1,\ldots,z_j,\ r,\gamma)$ where Π_{q^*} is the profit level for the optimal level of output q^*; and where r and γ represents the factor prices and technological parameters embedded in the cost function C(.). An offer function $\theta_{q^*}(z_1,\ldots,z_j,\ \pi,\gamma)$ indicates the minimum price a firm with a total cost function described by γ is willing to accept for a particular product design at constant profit when output quantity has been optimally selected. The firms' offer function is defined such that

$$q^*\theta_{q^*} - C(q^*,z_1,\ldots,z_j) = \pi$$

$$\text{and,}\quad \delta C/\delta q^* = \theta_{q^*} \tag{2.10}$$

and defines a family of indifference surfaces relating characteristics to the level of minimum acceptable money offers. Hence, $\delta\theta_{q^*}/\delta z_i$ reflects the marginal reservation supply price of z_i, which is increasing in z_i if C is convex (Rosen, 1974); and $\{\delta\theta_{q^*}/\delta z_i\}$ are a set of profit-compensated supply functions for characteristics z_i, $i=1,\ldots,j$.

In summary, $\delta\psi_{x^*}/\delta z_i$ and $\delta\theta_{q^*}/\delta z_i$ represent the maximum amount buyers are willing to bid for marginal quantities of z_i and producers marginal reservation supply price for z_i, respectively. For optimally chosen profit and output levels the characteristic market will be in equilibrium where input buyers and sellers are matched at the point of tangency of their respective value and offer functions. The equilibrium requires that the value of additional characteristic content to the input user must be equal to its marginal price, which must in turn be equal to the marginal cost to the producer of providing additional characteristic. The possible existence of many points of common gradient reflects the diversity of buyer technologies and producer cost conditions. The locus of multiple market clearing equilibria comprises the implicit or hedonic price function $r(z_1,\ldots,z_j)$.

The nature of the characteristics market equilibrium may be seen clearly in Figures II.1 and II.2 in which all characteristics z_k, $k\neq i$ are held constant at their optimum levels. The ψ functions for three input buyers with different production technologies and/or product mixes are plotted as ψ_1, ψ_2 and ψ_3 in Figure II.1. Indifference surfaces are shown only for the highest profit level attainable by each buyer given the locus of available market opportunities depicted by the hedonic price function $r(z_1,..,z_i,..,z_j)$. Figure II.1 also shows the θ functions corresponding to the highest attainable profit levels for three input producers who experience different cost conditions as θ_1, θ_2 and θ_3. In equilibrium, producers 1, 2 and 3 produce inputs I_1, I_2 and I_3; and inputs I_1, I_2 and I_3 are sold to buyers 1, 2 and 3, respectively. These conclusions are reexpressed in Figure II.2 in which market equilibrium is portrayed in terms of

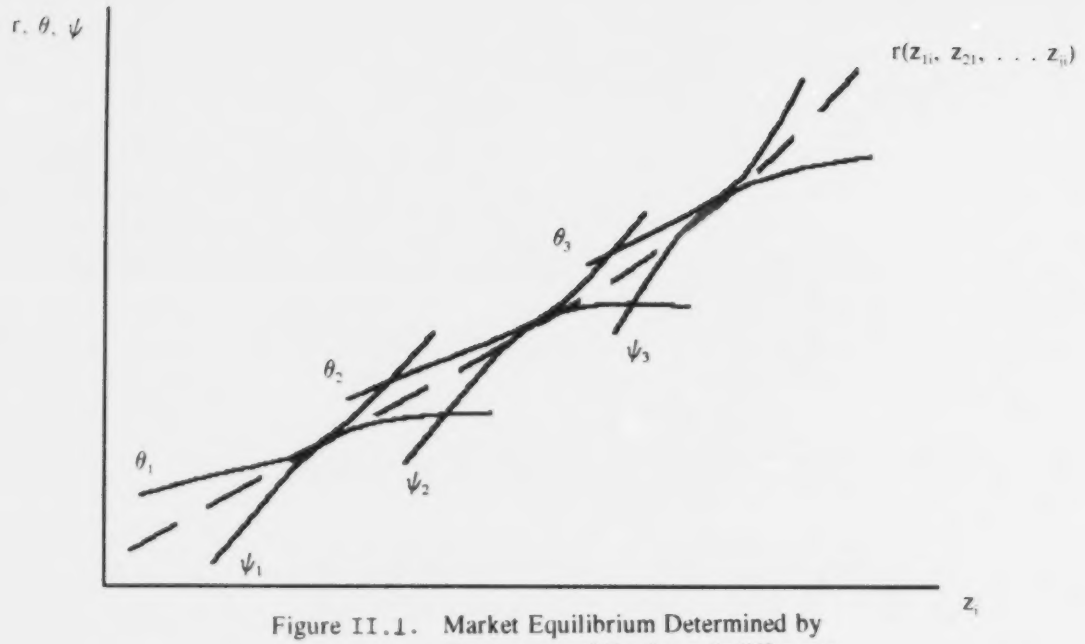


Figure II.1. Market Equilibrium Determined by Consumer and Producer Indifference Surfaces

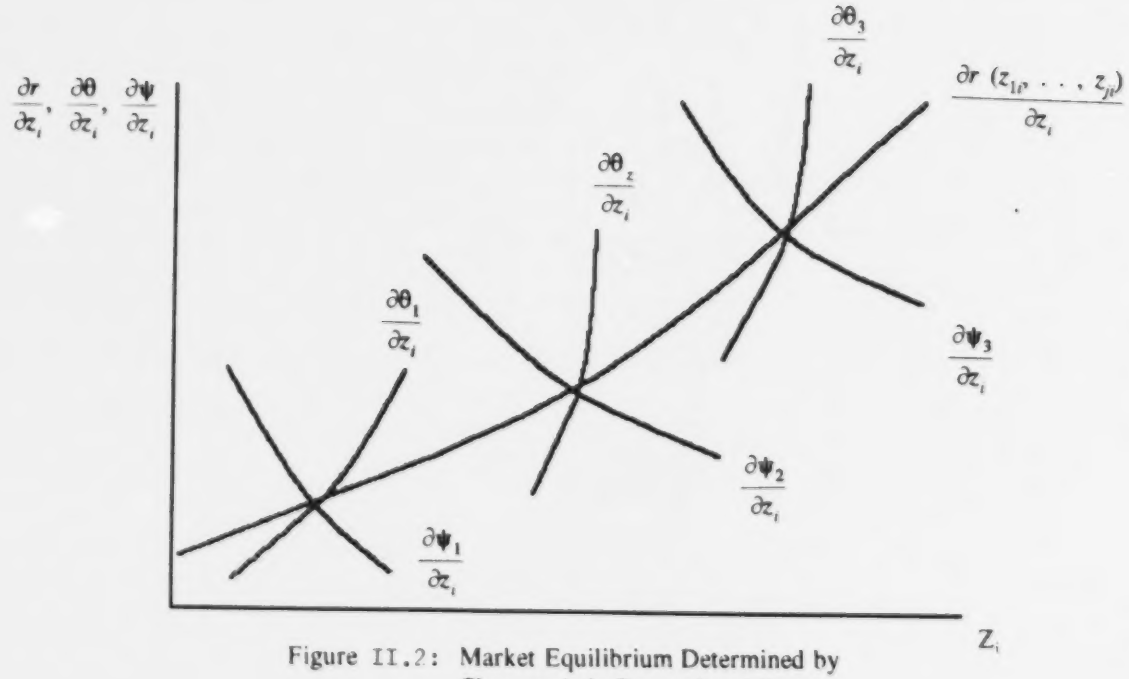


Figure II.2: Market Equilibrium Determined by Characteristic Demand and Supply Functions

the intersection of the derived characteristic demand and supply functions, $\delta\psi/\delta z_i$ and $\delta\theta/\delta z_i$. It is clear from both of these diagrams that the nature of the enveloping hedonic function $r(z_1,\ldots,z_j)$ is determined by the distribution of the parameters α and γ across all buyers and sellers.

Traditional approaches to operationalizing the input characteristic market model

Much of the applied literature in this field is centred around the estimation of the hedonic price function of equation 2.4. Assuming that $\delta z_{is}/\delta x_s$ and $\delta f/\delta z_{is}$ equal constants z_{is} and T_{is} respectively, the hedonic relationship can be estimated by regressing observed input prices, r_s, upon their characteristic contents. Marginal implicit characteristic prices are then calculated as $dr_s/dz_{is} = T_{is}$, for all characteristic $i=1,\ldots,j$.

Interpretation of implicit prices estimated in this way as buyers' marginal willingness to pay for additional characteristic content in inputs is common (see Veeman, 1987; Wilson, 1986). However, in the general case the envelope function $r(z_1,\ldots,z_j)$ reveals little about the underlying supply and demand conditions which generated it. As Figures II.1 and II.2 confirm, the function $r(z_1,\ldots,z_j)$ only tells us the slope of each buyers and sellers objective function at the point representing transactions which are actually observed[10]. Traditionally, the task of recovering underlying market structure parameters has involved a second-stage estimation based upon Figure II.2. In this phase estimated implicit marginal prices (evaluated at the amounts of characteristics actually traded) are treated as endogenous variables in the simultaneous estimation of the

[10] There are circumstances in which estimation of the hedonic function will be sufficient to identify the demand and supply structure of characteristic markets. In particular, if all input buyers are identical (i.e., there is no variance in α) then all value functions degenerate to a single surface which is traced out by the envelope function r(z). In this case, inputs will be differentiated in response to differences in producer attributes. Analogously, if buyers differ but sellers are identical (i.e., there is no variance in γ) then offer functions collapse to a unique surface and estimation of the hedonic price function is sufficient to identify supply conditions.

following 2j structural equations.

$$\delta r_i/\delta z_i = D^i(z_1,\ldots,z_j, A) \qquad i=1,\ldots,j$$

$$\delta r_i/\delta z_i = S^i(z_1,\ldots,z_j, \Gamma) \qquad i=1,\ldots,j \qquad (2.11)$$

A and Γ are the empirical counterparts of α and γ, and comprise the exogenous shift variables needed to identify underlying individual demand and supply functions. Although examples of second-stage implicit market estimation exist (Agarwal and Ratchford, 1980; Witte et al., 1979) a number of problems are well recognized. For example, the initial identification of the set of determinant characteristics is cited by Boyer et al. (1984) as "the most difficult task involved in applying the hedonic approach". Failure to measure a relatively exhaustive set of product characteristics (and buyer and/or seller attributes) will bias estimated coefficients on measured variables when they are correlated with those which are left unmeasured (Epple, 1987).

There may also be substantive problems with the use of buyer and seller attributes as instruments in the identification of demand and supply parameters. This is a result of the fact that the intimate relationship between equilibrium in a characteristic market and the matching of buyer and seller attributes imposes restrictions in the second-stage estimation on the relationship among measured variables and random components. However, Epple (1987) shows that careful specification of errors and orthogonality conditions can permit consistent estimation of structural parameters using the system in equation 2.11 . As an alternative procedure, Bartik (1987) suggests the use of instrumental variables to exogenously shift the hedonic price function. More recently, Goodman (1989) shows how preference information derived from factorial survey analysis can be interpreted as reflecting willingness-to-pay and, when linked to a set of market-determined hedonic prices, $\{\delta r_i/\delta z_i\}$, can circumvent the need to estimate the second stage hedonic system.

Hedonic prices, implicit markets and wood characteristics

The concept of a 'hidden' market in which characteristics are implicitly bought, sold and priced is clearly of direct relevance to the problem of introducing the dimension of wood quality to forest growing and investment analysis. In selecting between various forest management regimes wood suppliers implicitly select the position in characteristic space (or portfolio of positions) which their product will occupy[11]. On the other hand, wood resource quality influences the profitability of wood processing via its effects on product outturn, cost and/or final product quality. Furthermore, since wood markets define prices in terms of quantity (for example, dollars per cubic meter or bone dry tonne) the prices of all other quality related characteristics remain unobservable. The hedonic market model offers a convenient and theoretically consistent means of 'untying' the wood characteristics bundle and of gaining insight to the elemental forces which drive the market for stumpage.

There are, however, few examples of empirical studies which apply the hedonic approach to forest sector markets[12]. Furthermore, without exception, these examples stop short of exposing the structural features of characteristics markets as suggested by Rosens' second-stage procedure. The lack of empirical work in this area can be traced to several factors. First, the limited availability of reliable market based price and characteristic data bounds the extent to which traditional hedonic methods can be usefully applied. For example, even though more than a quarter of all coastal log sales in British Columbia occur in the Vancouver Log Market (Council of Forest Industries of British Columbia, 1987) published data is aggregated across sales for the same species and grade, making it difficult to identify the information about the attributes of

---

[11] For example, fertilization may reduce wood density (McKimmy, 1986) and increase ring width (Briggs and Smith, 1986), while thinning may result in trees with higher taper and large limb size (Bendtsen, 1978).

[12] These examples are documented in Chapter IV: Review of Wood Quality Literature.

buyers and sellers which is needed to estimate underlying offer and bid functions. Even estimation of a simple hedonic price function using this data is frustrated. Logs are graded upon the basis of their meeting certain minimum criteria in terms of a variety of characteristics (such as length, diameter, ring width and estimated proportion of clear wood) using an alpha nomenclature A to Y. Therefore, unless supplemented by additional information on average characteristic content, a hedonic function is constrained to separating the effects on price of only two variables, species and grade[13].

A second difficulty stems from the fact that hedonic procedures draw upon the prices and characteristic content of observed market transactions from which current and/or historical implicit valuations are derived. Only characteristics across which actual products vary may be included: and the range of characteristic variation which may be analyzed is restricted to the range of actual variation. It is, however, future characteristic values which are of relevance to current production decisions. While this is true of all markets it proves particularly troublesome in the case of wood crop planning due to the unusually long production period involved in product manufacture[14]. During the course of a single production cycle, technological and institutional changes will shift multi-characteristic production surfaces and will cause changes in marginal wood characteristic prices over and above those caused by changes in the distribution of buyer and seller attributes. Furthermore, these effects may be substantial as implicit wood

---

[13] Sterling Wood (1988) report Vancouver Log Market data which has been supplemented by information on the price/characteristic relationships obtained from industry sources and interpolation. This data is used in Chapter Seven to derive current marginal prices for the following characteristics; species, dbh and tree height.

[14] Sutton (1986) makes this point with respect to forest crop planning in New Zealand. Research has shown that, for *Pinus radiata* "tree quality and size at harvest were very largely determined by the treatment prior to age 9 years and that total flexibility is not possible. This meant that forest growers were largely predetermining the market prospects of their plantations 20 to 30 years before harvest".

characteristic markets will be affected by changes in forest growing and wood processing industries and in the markets in which wood products compete (and in which derived wood characteristic demands are determined). The potential complexity of these effects suggests that simple trend extrapolation, even over a single production cycle, is unlikely to adequately capture the nature of shifts in offer, bid and equilibrium price surfaces. Consequently, to be usefully applied to the problem of formulating forest crop plans conventional hedonic estimation procedures need to be modified to take stock of both the absence of observable data and the impact of technological and other market changes upon the structure of characteristics markets, whilst preserving the essential flavour of implicit market theory.

This thesis suggests an alternative approach which relies upon experimental survey, rather than observable market, data. It draws heavily upon the conceptual and practical expertise of market researchers, developed to address broadly similar questions about product quality and positioning. Furthermore, the suggested approach attempts to produce estimates of future, rather than current or historical, market parameters by inviting survey respondents to integrate their beliefs about the nature and extent of technological and institutional change prior to revealing their preferences over sets of designed multi-characteristic goods. The following chapter describes conjoint analysis, a particular type of multi-characteristic judgement model which has found favour amongst market researchers due to its sound theoretical underpinning and established empirical procedures, and establishes the way in which applied conjoint analysis can be used to provide estimates of the preference parameters of buyers in hedonic markets.

Chapter III: Conjoint Analysis: Price-Compensated Profit Surfaces and Scenario Conditioned Judgements

The term 'conjoint analysis' refers to a suite of techniques used primarily by market researchers to estimate characteristic utilities based on subjects' responses to combinations of multiple decision characteristics. Conjoint analysis and hedonic market analysis are alike in that both are based on the twin assumptions that a product can be described as a tied bundle of characteristics and that it is consumers' preferences for various characteristic levels which determine their evaluation of overall product value or desirability. Furthermore, both methods attempt to 'uncover' the implicit weights ascribed to various product characteristics by estimating the functional relationship between some measure of overall product 'desirability' and characteristic content. Finally, although developed within the context of final consumption decisions, both methods find more general applicability in markets for production related inputs.

The two approaches are unalike in at least two important ways. The first point of departure lies in the type of data used in empirical applications of the two approaches. On the one hand, hedonics draws upon the information contained in the observed preferences for differentiated products as revealed in actual market transactions. On the other hand, conjoint analysis seeks to interpret the information contained in the stated preferences for designed product concepts (defined by specified characteristic combinations) as revealed by survey responses.

Each data source has advantages and disadvantages. The great advantage of models based on revealed preference data is that, to the extent that they attempt to explain real choice behaviour, they have a certain prima facie validity. The ability of models based on experimental data to describe behaviour in real environments, with which we are ultimately concerned, is far less certain. When comparable real markets exist, the external validity of experimentally-based models can be formally explored (Louviere and Horowitz, 1988). In cases where choice

behaviour is not exhibited in real markets questions of external validity may be impossible to resolve[15].

An advantage of using data which has been generated experimentally is the ability to control both the range and nature of characteristic variation. This means that responses to products for which markets do not exist can be elicited. It also ensures that sufficient orthogonality among characteristics (i.e., independent variables) exists in the data to permit the unconfounded estimation of key effects and the testing of competing hypothesis about respondent behaviour. In addition, it implies that sufficient data can be generated to permit the estimation of individual-level conjoint functions. This adds a richness to behaviourial analysis which is not possible when the limitations of observed data compel the use of aggregate-level analysis.

The second difference between the approaches concerns the assumed model of individual judgement and consumer behaviour which underscores the analytical techniques. As reviewed in the previous chapter, the hedonic model emerges as a result of the optimizing behaviour of economic agents in competitive markets when characteristics replace commodities as arguments in profit (utility) and cost (production) functions. On the other hand, conjoint analysis encompasses a wide range of "paradigms, methods and analytical techniques", all of which involve "different assumptions, methods of analysis, and experimental procedures" (Louviere, 1988a).

Analytically at least, hedonics finds its closest parallel in the paradigm of metric conjoint analysis which is based on a particular conceptualization of human information processing, namely Information Integration Theory (IIT). IIT is " a theory about the behaviour of numerical

---

[15] In some cases external validity may be impossible to establish ex ante while it may be readily determined ex post. For example, the validity of experimentally-based models for explaining choice behaviour with respect to products which do not yet exist is impossible to establish. However, once the product has been introduced external validity may be checked.

data in response to multiple pieces of information" which posits that simple algebraic conjoint models are valid approximations to the unknown and unobservable judgement and decision processes of consumers (Louviere, 1988).

Louviere summarizes the essence of IIT in three propositions. These propositions, recast in terms of the evaluative procedure of an input buyer, are as follows:

(i) An input buyer's assessment of the unobserved profit (Π_h) associated with the hth brand of input is linearly related to his rating response for that brand (R_h). Therefore,

$$\Pi_h = a + bR_h + e_h \tag{3.1}$$

where e_h is a well behaved error term, such that $e_h \sim N(0,\sigma^2)$.

(ii) the category-rating scale used by respondents in a conjoint experiment is approximately interval in measurement level (i.e., it is a cardinal measure with arbitrary zero and unit), and

(iii) the buyer's response strategy reveals his decision strategy which can be approximated by a conjoint model which can be statistically estimated and tested.

The simplest and most widely used conjoint model is the adding, or main-effects, model. This is written below for an input which is defined in terms of three determinant characteristics, each of which occurs at one of three different levels; p,q and r.

$$\Pi_{pqr} = \Pi_h = C + V(z_{1p}) + V(z_{2q}) + V(z_{3r}) \tag{3.2}$$

where z_j is the consumer's perceptual belief about the position of the hth brand on the jth characteristic. In other words, the assessed profitability of using good h as a production input is the sum of the part-worth profitabilities associated with the levels of the three determinant characteristics. The empirical counterpart of equation 3.2 is,

$$R_{pqr} = C + V(z_{1p}) + V(z_{2q}) + V(z_{3r}) + e_{pqr} \tag{3.3}$$

R_{pqr} is the buyer's observed rating of the experimental stimuli embodying the pth, qth and rth

levels of characteristics 1, 2 and 3 respectively[16].

One of the strengths of this metric conjoint paradigm is that IIT embodies a well developed theory of errors which supports the testing of alternative models of consumer decision-making using analysis of variance or multiple linear regression. Conceptually, a more general form for equations 3.2 and 3.3, such as a simple polynomial, is appealing as it includes, as subsets, decision processes in which characteristics are complements, substitutes or independent.

The conjoint relationship is estimated and the significance of characteristic effects is tested using data generated via a conjoint experiment in which subjects are requested to rate a set of designed multi-characteristic product concepts. However, testing for all main and interaction effects suggested by the polynomial conjoint specification would require that each respondent must rate each of the (p).(q).(r) possible product stimuli at least twice (Louviere, 1988). While this may be feasible in small experiments the number of possible stimuli grows quickly as the number of characteristics and characteristic levels grow. Therefore, 'fractional factorial' experiments are often used in which a sample of stimuli are selected from the complete (p).(q).(r) factorial design.

The use of orthogonal arrays as a main-effects estimation design is quite general. Orthogonal arrays ensure that selected effects are not confounded (and hence can be identified) and enable the precision of parameter estimates to be controlled a priori. However, the use of fractional designs implies that information is lost and estimates of selected effects will only be accurate when there is no colinearity between included and sacrificed information. For example, experimental data collected using a fractional design can only be used to estimate the main-effects only model in equation 3.2 with confidence if all interaction and higher-order effects are

---

[16] The use of IIT models to estimate part-worth utilities from ratings data is called Functional Measurement.

insignificant.

When constructing conjoint experiments researchers are confronted with a number of additional design related issues[17]. For example, researchers must decide how to present product stimuli to respondents (i.e., verbal or paragraph description, or pictorial representation) and what form the dependent variable is to take (i.e., preference, liking, intention to buy). As with hedonics, one of the most important design tasks involves identifying the set of determinant characteristics and selecting the levels which each characteristic is to take. This task is often a substantial empirical problem in itself and failure to measure a relatively exhaustive set of product characteristics and to express them in terms which respondents understand can distort estimated effects.

A number of approaches to characteristic identification are suggested. Formal procedures, such as Kelly's repertory grid and multi-dimensional scaling, involve the development of constructs (or dimensions) based upon individual's perceptions of product similarity or dissimilarity. More informal procedures rely on reviewing relevant technical and trade literature, direct observation of behaviour and/or eliciting the opinions of market participants via group or individual interviews or discussions. In some cases, the set of experimental characteristics is limited to those which product managers are able (and willing) to manipulate (Currim et al., 1981).

In many problems of applied and academic interest these methods will identify a large number of influential characteristics and judgement experiments quickly become unrealistically large. In such cases experimenters can simplify judgement tasks by using various blocked fractional designs without having to arbitrarily reduce the characteristic set (Green, 1974).

---

[17] A number of these issues are briefly discussed here. Louviere (1988) provides a useful theoretical discussion of many of these issues, while Cattin and Wittink (1982) and Green and Srinivasan (1978) review commonly used conjoint practices.

Alternatively, if characteristics can be grouped a priori into logical or functional subsets, or composite concepts, a separate conjoint task can be performed for each subset. The way in which composite concepts are integrated or processed is then elicited through a higher-order conjoint task in which subjects respond to alternatives defined by varying levels of the composite concepts (Louviere, 1987).

Three considerations are important in deciding on the range over which characteristics are permitted to vary and the level of designed inter-characteristic correlation. First, the 'believability of' or 'familiarity with' stimuli, and hence the prima facie validity of judgement based responses, will be improved when characteristic ranges and inter-characteristic correlations are constrained to be similar to those experienced in analogous actual markets. On the other hand, since much research focuses on identifying market responses to new or hypothetical products it is appropriate that the range of variation in characteristic levels and the extent and nature of designed characteristic correlation reflect technical production possibilities, even if these are not reflected in current market offerings. Finally, for a given level of response validity, a wider range of characteristic variation and/or orthogonality of characteristics will improve the precision of parameter estimates. The final design of any conjoint experiment will, therefore, represent an attempt to balance the need to reflect technological possibilities and to capture estimation efficiencies against the need to ensure judgement validity.

Typically, experimentally generated rating data are used to estimate individual-level conjoint functions. Individual differences in the worth ascribed characteristics are then identified by clustering subjects on the basis of their estimated coefficient vectors or by regressing estimated part-worths on measures of individual difference such as sex, age and income[18]. Alternatively,

---

[18] Within the context of input characteristics the vector of individual differences might include measures of product mix and technology.

individual response data are pooled and an aggregate model of judgement is estimated in which utility depends both on product design and individual attributes.

Estimated coefficients on characteristics represent interval scale estimates of unknown $V(z_j)$ parameters. Since judgement data is generated independently of considerations of product supply, coefficients can be interpreted as measures of relative characteristic desirability and can be seen as reflecting the same elemental forces which generate characteristic valuations in implicit market bid functions[19]. Unlike implicit market bid parameters, however, conjoint coefficients are not expressed in a dollar metric[20].

Input-price compensated profit surfaces

The inclusion of bundle price in the characteristic set in conjoint experiments suggests one way in which estimates of relative characteristic desirability can be converted to a common dollar metric and, hence, used as an estimate of implicit market bid parameters. Consider an input which can be defined in terms of $j+1$ characteristics, $(z_1,\ldots z_j, r)$, where r is unit price. If subjects are invited to rate designed input bundles in terms of how desirable an input supply of this nature would be then the empirical conjoint model $R(z_1,\ldots z_j, r)$ of equation 3.3 approximates the underlying profit function $\Pi(z_1,\ldots,z_j, r)$, of equation 3.2 evaluated at the optimally selected input bundle[21].

---

[19] This assumes that individual's judgement responses in an experimental conjoint situation accurately reflect their behaviour in real market situations. This issue is addressed briefly in Chapter VII.

[20] In fact, since conjoint techniques measure differences in utilities, and not absolute magnitudes, the common practice of making inter-respondent characteristic utility comparisons is questionable.

[21] This assumes that respondents have implicitly selected the optimal input quantity prior to stating bundle ratings.

Now consider two input designs which differ only in terms of their content of characteristic i, such that the two designs contain levels z_{ip} and z_{iq} respectively, where $p < q$. The maximum amount that an individual would be willing-to-pay for an increase in the level of characteristic z_i from z_{ip} to z_{iq} in their optimal input bundle can be defined by a new function Δr, where $\Delta r = r^1 - r^0$ such that $R(z_1,\ldots,z_{ip},\ldots,z_j, r^0) - R(z_1,\ldots,z_{iq},\ldots,z_j, r^1) = 0$. When evaluated across all levels of z_i, Δr traces out a function which represents a buyer's demand price for an additional unit of z_i, given a particular technology and assessed for particular levels of output price and profit. Evaluated for different initial levels of R (or Π), Δr maps out a series of input-price compensated characteristic value surfaces which are direct counterparts of the implicit market value functions, $\delta\psi_{x^*}/\delta z_i$[22].

If conjoint coefficients are used in this way to provide estimates of implicit market willingness-to-pay parameters, the estimated conjoint equation must permit parameters which are consistent with those suggested by the behaviourial assumptions of the implicit market model. More specifically, the conjoint estimation must permit input-price compensated profit surfaces vary between individuals and to be decreasing and non-linear in characteristics. Clearly, the first of these could be achieved by estimating individual-level conjoint equations, while the latter requires careful selection of the functional form for conjoint equations.

Scenario conditioned conjoint judgements

The judgements elicited in traditional conjoint experiments reflect respondent's current attributes and are conditioned by their beliefs about the existing purchase environment. For example, rating judgements about multi-characteristic production inputs would reflect

---

[22] Clearly, the 'common currency' into which characteristic utilities are converted need not be dollars. The currency can be any continuous, quantitative characteristic varied in a conjoint task.

respondent's perceptions of ruling output prices, prices and availability of substitute goods, technological possibility sets and other market and institutional constraints. Consequently, estimated part-worths reflect current characteristic valuations. However, as was argued earlier, future characteristic values may differ substantially from those witnessed in todays markets or implied by experimental ratings revealed contingent upon current circumstances. Where production processes are long, as with wood growing, there is a clear need to base current production decisions on expected future characteristic values which anticipate the impact of structural shifts in characteristic markets.

In order to estimate expected future characteristic weights conjoint judgements must, therefore, be conditioned by the set of environmental conditions which are expected to exist in the future. When future states can be anticipated with certainty or a strong consensus as to probable conditions can be reached, future circumstances can be described to subjects and ratings, contingent upon the described future, elicited. Resulting conjoint coefficients can then be interpreted as conditional interval scaled estimates of unknown preference (or profitability) parameters.

In some cases identification of a single future scenario is impractical or would mask the nature and extent of uncertainty surrounding possible future circumstances. Respondents, therefore, may be asked to replicate a designed rating task conditional upon a number of alternative described future states. Vectors of individual conjoint coefficients can then be tested to establish the effect of future states upon revealed characteristic valuations.

While the task of constructing the set of future states can be undertaken independently of the conjoint experiment it may, in some applications, be possible and convenient to combine forecasting and characteristic judgement tasks in a single experiment. This will be appropriate when the relevant samples for the two tasks coincide. One possible approach would be to invite

conjoint participants to base their rating judgements on their personal expectation of the state in which future purchases will be made. Assumed future states can then be empiricized by asking subjects to respond to a series of open or closed-ended questions relating to their implied assumptions about various environmental dimensions. If individual subjects are then clustered on the basis of their expectation profiles implicit market willingness-to-pay maps can be constructed for each cohort and inter-cohort differences tested.

The preceding two sections of this chapter have explained how conjoint analysis can be extended to provide both dollar estimates of input buyers' willingness-to-pay for production related characteristics and characteristic valuations which are conditioned by circumstances other than those which are current. These extensions are combined and illustrated via an empirical investigation of British Columbia's Coastal wood characteristic market which is reported and discussed in subsequent chapters of this thesis.

Traditional conjoint models and procedures, however, offer powerful tools for eliciting and depicting buyer preferences. Therefore, the data collected in this thesis is also used to estimate conjoint models with more traditional interpretations. The beta distributed conjoint model (BDCM) in particular provides a useful consensus representation of rating judgement data, while a relatively new representational scaling model, known as Best-Worst Scaling, is used to analyse the data from a largest difference experiment and to estimate a set of numerically scaled and testable crop planning objective weights. This chapter is concluded with descriptions of these two models.

A Beta Distributed Conjoint Model

One of the strengths of conjoint analysis as described above is the ability to investigate individual-level judgements directly. This adds a richness to behaviourial analysis which is not

possible when data limitations compel the use of aggregate-level analysis. Often, however, our interest will be in aggregate-level effects or perceptions and some method of organising individual-level data into interpretable aggregate-level information is required.

At least two approaches to aggregation are common in marketing applications of conjoint analysis. First, if we assume that all individuals have identical preferences, response data can be pooled and a single 'average' or 'representative' function for the population computed. Often sub-groups of the population for whom this might be a reasonable assumption are identified by clustering subjects on the basis of the similarity of their conjoint responses or the value of part-worths estimated at the individual-level[23]. Separate 'representative' functions are then estimated for each identifiable sub-group. Alternatively, a single preference structure can be imposed on all individuals and a separate component of the utility function, which depends on individual-level attributes, specified.

A second class of aggregation techniques are known as Response Surface Methods. Individual-level response functions are often estimated and used in a choice simulator to determine aggregate responses to changes in product and market variables. Determining the functional relationship between these responses and product and market variables lets us predict aggregate responses to hypothetical product changes[24]. In a recent paper Rao and Zahoric (1990) develop a new response surface technique, called the Beta Distributed Conjoint Method

---

[23] Segment or cluster membership can then be tested to determine the variates which determine cluster membership.

[24] In order to simulate aggregate choice using individual utility parameters estimated from judgement data it must be assumed that (i) the 'best' product within a competitive scenario is the one for which predicted utility is highest and (ii) that, under forced choice conditions, an individual would select the 'best' alternative. These assumptions require that the following be true: "(a) individuals are perfectly transitive and consistent, (b) there is no bias in the estimated parameters, (c) individuals are aware of all the alternatives and possess perfect information about their attributes, and (d) there are no income, time or other constraints to cause individuals to choose something other than the alternative with the highest predicted utility" (Louviere, 1988).

(BDCM), for relating product characteristics to aggregate-level preference responses[25].

The basic notion underlying the BDCM is that changes in a product's profile will change the shape of the distribution of ratings obtained from a group of respondents in a standard metric conjoint experiment. Moreover, the shape of the response distribution can be functionally related to the set of product characteristics directly and the shape of the distribution of responses for new or holdout profiles can be predicted. As the name suggests, the BDCM uses the two parameter beta distribution to describe aggregate conjoint responses. The strength of this distribution is that it represents a family of functions capable of taking on a wide variety of shapes over a finite interval. For example, for various parameter values the shape of the beta function may be uniform, bell-shaped, triangular or J-shaped, to name a few. This flexibility means that a wide range of response distributions can be represented by a single distribution.

On the unit interval of the response measure q, the probability density function associated with the beta distribution is

$$f(q;\alpha,\beta) = ((1/B(\alpha,\beta))q^{\alpha-1}(1-q)^{\beta-1} , \qquad 0<q<1 \qquad (3.4)$$

where α and β are non-negative parameters, and $B(\alpha,\beta)$ is the Beta function which ensures unit area under the curve on the unit interval[26].

The BDCM assumes that the distribution of responses to each product stimuli belongs to a family of beta distributions whose parameters, α and β, uniquely characterize the distribution

---

[25] An alternative to both approaches is to observe (via the use of discrete choice experiments) and to model the choices that individuals make in various situations directly. Thus, rather than having to assume that consumers make choices in a particular way, appropriately designed choice experiments enable one to test alternative choice strategies. Choice experiments have the advantage of resembling real choice environments more closely than do other forms of judgement experiments and avoid the need to impose order or metric assumptions on response data. However, in order to estimate utility parameters and to conduct statistical tests of their significance, both product alternatives and competitive scenarios, or choice sets, must be designed.

[26] The Beta function, $B(\alpha,\beta) = \Gamma(\alpha+\beta)/\Gamma(\alpha)\Gamma(\beta)$, where Γ is the gamma function.

and are related to product characteristics (Z) such that

$$\alpha = f_1(Z) \text{ and } \beta = f_2(Z) \tag{3.5}$$

Conveniently, α and β, which have no clear intuitive interpretation are related to the more familiar first and second non-centralized moments (m_1 and m_2) of the response distribution in the following way

$$\hat{\alpha} = m_1(m_1-m_2)/(m_2-m_1^2) \tag{3.6.1}$$
$$\hat{\beta} = \hat{\alpha}(1/m_1-1) \tag{3.6.2}$$

Clearly, m_1 and m_2 are themselves functionally related to product characteristics such that

$$m_1 = g_1(Z) \text{ and } m_2 = g_2(Z) \tag{3.7}$$

Given a sample's rating responses to a set of designed product profiles m_1 and m_2, and hence $\hat{\alpha}$ and $\hat{\beta}$, can be easily calculated for experimental profiles. Furthermore, estimating the functions g_1 and g_2 enables these parameters, which completely describe the response distribution, to be predicted for non-experimental profiles.

However, since the shape of the response distribution is determined jointly by the parameters α and β the estimated equations relating m_1 and m_2 (and indirectly, $\hat{\alpha}$ and $\hat{\beta}$) to product characteristics will not be easy to interpret. Consequently, Rao and Zahoric (1990) recommend evaluating the relationship between product characteristic levels and the proportion of the population whose responses fall within a specified range directly. This is done by using the fitted beta distribution to predict the proportion of responses which lie within this range for each product stimuli. This new variable is in turn fitted to a function of product characteristics and the estimated equation used to predict the proportion of favourable responses to any holdout or other profiles of interest.

Hence, the recommended approach involves calculating m_1, m_2, $\hat{\alpha}$, and $\hat{\beta}$ as before and

using these to create a new variable CCDFBETA(δ) where

$$\text{CCDFBETA}(\delta) = \int_{\delta}^{1} f(q;\alpha,\beta)dq \qquad 0 \leq \delta \geq 1 \tag{3.8}$$

CCDFBETA(δ) is the proportion of beta distributed responses which fall above a specified value on the unit interval, namely δ[27]. This variable is itself related to product characteristics (Z) such that

$$\text{CCDFBETA}(\delta) = h(Z) \tag{3.9}$$

Estimating equation 3.9 enables the proportion of favourable responses to non-experimental profiles of interest to be predicted[28].

The way in which individual respondent characteristics affect the relative attractiveness of product profiles may be explored within the BDCM as follows. First, separate BDCMs can be estimated for various classes of respondents and differences in the resulting conjoint functions tested. Alternatively, where degrees of freedom permit, individual subject attributes may be included as independent variables in BDCM functions (g_1, g_2, m_1, m_2 and h) directly. Significant attribute coefficients indicate respondent traits which are associated with varying levels of product profile approval or disapproval[29]. Finally, one can create a new variable which measures the percentage of respondents with a particular attribute among those who give a favourable rating

---

[27] CCDFBETA(δ) is calculated as 1-CDFBETA(δ) where CDFBETA(δ) is the incomplete beta function, or the percent of beta-distributed responses which falls below δ.

[28] Alternatively, the actual proportion of responses which lie within a specified range could be modelled as a function of product characteristics directly. However, in applications of the BDCM Rao and Zoharic (1990) find that the "imposition of the beta distribution on the data, and the use of theoretical incomplete cumulative density function, out performs the fits and predictions obtained from using actual data".

[29] Since there will rarely be sufficient degrees of freedom to include attribute variables in anything but a main effects form, this approach does not identify which product characteristics motivate different types of individuals responses.

to a profile. Regressing this variable on product profiles will indicate which characteristics lead to a greater proportional representation of respondents with the given attribute among those responding favourably to a profile.

Best-Worst Scaling

In addition to the conjoint methods described above experts' judgements about timber resource characteristics are analyzed in this thesis using a representational scaling or measurement model. Representational scaling enables practitioners to array a set of items (for example brands, objects, characteristics) along an interval scale on a dimension of managerial or research interest. Representational measures are based on some model or theory about the type of behaviour which underlies individuals' judgements which enables interval scale values to be estimated, interpreted and tested. A relatively new scaling model, known as Best-Worst scaling (Louviere and Woodworth, undated; Finn and Louviere, 1993 (forthcoming)), is used in this thesis to analyze largest difference judgement data. The Best-Worst scaling model is intended as an alternative to index measures which, although straightforward to apply, are not representational; and to multi-dimensional scaling which, although representational, can be unduly complex to implement. The Best-Worst scaling model is also attractive to economists as its logic can easily be cast in familiar terms of Random Utility theory.

The Best-Worst scaling model can be summarized as follows[30]. The scaling of items is based on judgements of which two items in a set exhibit the largest difference on the chosen

---

[30] Louviere and Woodworth (undated) describe Best-Worst scaling as "a multinomial extension of the Thurstone (1927) Case V Paired Comparison model" and the technique's behaviourial justification as an extension of the same authors Law of Comparative Judgement.

dimension(s)[31]. It is assumed that judgements represent fallible reports of the two items whose true difference is largest in each set. Thus observed judgements have a systematic and a random component. If the random component is independently and identically distributed as a Type 1 extreme value distribution then choice frequencies, aggregated across both individuals and choice sets, can be modeled as a Multinomial Logit (MNL) model and scale values derived from maximum likelihood parameter estimates.

The model, expressed in a Random Utility framework, is set out more formally below. Suppose that a group of r subjects are asked to name the best (or highest, or most) and the worst (or lowest, or least) alternatives within each of c designed choice sets, constructed from p items, with respect to a defined dimension. The choice made by individual r in choice set c is denoted

$$f_{rbwc} = \begin{cases} 1 \text{ if alternative b is best and w is worst} \\ 0 \text{ if some other best/worst combination is chosen} \end{cases} \quad (3.10)$$

Assume that individuals make these judgements by comparing (implicitly at least) each pair of alternatives in a set and selecting the pair with the greatest utility difference as the best/worst combination. Now, if $U_1 \ldots U_p$ denote the true utilities of the p items on the dimension of interest then the true utility difference between items i and j is[32]

$$s_{ij} = U_i - U_j \quad (3.11)$$

However, subjects reveal their judgements on the basis of perceived (rather than true) utility differences between items. Subject r's perceived utility difference between items i and j in choice set c is

---

[31] Louviere and Woodworth (undated) illustrate the model with an application in which six fast food restaurants are scaled with respect to nine dimensions, such as price, variety and cleanliness. The next chapter of this thesis reports the results of applying the model to a hierarchical problem in which three higher-order and eleven lower-order timber growing objectives are scaled with respect to a single dimension, namely commercial desirability.

[32] If item i is better than item j, s_{ij} is positive. If the opposite is true, s_{ij} will be negative.

$$d_{rijc} = s_{ij} + e_{rijc} \tag{3.12}$$

where e_{rijc} is a random component which represents the error which individual r makes in assessing the difference between items i and j in choice set c. Now, assuming that individual r will choose item b as best and w as worst in choice set c if $d_{rbwc} \geq d_{rijc}$ ($\forall$ i,j), then the probability of the individual selecting $f_{rbwc} = 1$ is

$$Pr[f_{rbwc} = 1 | r,c] = Pr\{U_b - U_w + e_{rbwc} \geq U_i - U_j + e_{rijc};\ \forall\ i,j\} \tag{3.13}$$

Assuming that the error term follows a Type 1 extreme value distribution with distribution function $F(e) = \exp(-\exp(-e))$, the conditional probability that subject r will actually choose item b as best and item w as worst in choice set c can be represented by the MNL model (McFadden, 1974)

$$Pr[f_{rbwc} = 1 | r,c] = \exp^{Sbw} / \sum_{i \subset C} \sum_{j \subset C} \exp^{Sij}$$

$$= \exp^{(Ub - Uw)} / \sum_{i \subset C} \sum_{j \subset C} \exp^{(Ui - Uj)} \tag{3.14}$$

Furthermore, if (i) true scale values $U_1 \ldots U_p$ are the same across all r subjects and (ii) if each subject's repeated choices are conditionally independent in different choice sets, aggregate choice frequencies follow a product-of-multinomials model. In other words,

$$Pr[F_{bw} = \Gamma] = \prod_{i=1}^{c} Pr[F_{bwi} = \Gamma] \tag{3.15}$$

where c is the total number of choice sets and $F_{bw} = \Gamma$ represents the aggregate frequency with which individuals choose b as best and w as worst in a choice set[33]. To apply the model observed or revealed choice frequencies, aggregated across subjects, are fit to the MNL model in equation 3.15 using a maximum likelihood procedure in which choice sets are represented by

---

[33] Therefore, $F_{bwc} = \sum_{j=1}^{r} f_{jbwc|c}$, where r is the number of respondents expressing judgements in choice set c.

a categorical identifier.

Two key behaviourial assumptions enable the Best-Worst model to be formulated as in equation 3.15. First, it is assumed that s_{ij} is the same for all subjects; in other words, true characteristic utility values are the same for all individuals. For many applications this will not be true and the perceived distances between items will vary between subjects due to both random variations and to differences in mean positions. In this case, true utility differences, s_{ij}, should be modeled as a function of subject attributes. In other words, assuming a linear form of conditional indirect utility function, individual r's utility for item i (U_{ri}) is specified as

$$U_{ri} = \alpha_0 + \alpha_1 x_{r1} + \alpha_2 x_{r2} + \ldots + \alpha_k x_{rk} \qquad (3.16)$$

where x_{rk} represent k respondent attributes, and equation 3.14 estimated.

Louviere and Woodworth (undated) suggest two additional ways of handling this problem. One approach is to identify relatively homogeneous population sub-groups on the basis of some discriminating subject attribute(s) such as age or occupation, and to fit the product-of-multinomial model to choice data aggregated across each sub-group. Alternatively, the model could be fit to individual level data and estimated scale values modeled as a function of subject attributes.

The second key assumption is that successive choices made by the same individual in different choice sets are independent. Violation of this assumption may result in potentially more serious problems than those posed by the existence of between subject differences in mean item positions. Again Louviere and Woodworth suggest two approaches to dealing with this. The first, which they dismiss as impractical due to it being computationally formidable, is to model perceived differences, d_{rijc}, in equation 3.12 as a function of an individual specific "self-consistency coefficient"[34]. Alternatively, one can attempt to reduce the likelihood of the

---

[34] In other words, $d_{rijc} = S_r * s_{ij} + e_{rijc}$, where S_r is a random quantity associated with each individual.

problem occurring by ensuring that individual choice differences are adequately explained by the set of subject attributes specified in the model. This could be done by improving model specification either by specifying scale values in equation 3.14 as a function of subject attributes or by estimating the model for like sub-groups as described above. Estimating the model in equation 3.15 in cases in which the assumption of independent successive choices fails, would result in estimated standard errors which are biased downwards and tests of parameter significance that are suspect[35]. However,as Louviere and Woodworth note, if one is interested primarily in positioning items on a particular dimension and not in testing hypothesis about specific scale values, as is generally the case, ML estimates of the product-of-multinomials model will be consistent.

The Best-Worst scaling model is applied to largest difference judgement data. Louviere and Woodworth suggest that judgement data be obtained via an experiment in which respondents are asked to state the 'best' and the 'worst' item in a number of comparison sets designed using an orthogonal, main effects fraction of a 2^p factorial (where p is the total number of items to be scaled)[36].

The method of Best-Worst Scaling is based on an explicit theory of judgement behaviour.

---

[35] Louviere and Woodworth (undated) suggest adjusting estimated standard errors by multiplying them by the square root of the number of choice sets to provide conservative tests of parameter significance.

[36] Experiments constructed using this type of design satisfy necessary and sufficient conditions for model estimation and do so with comparatively few choice sets. For example, in the experiment described in the next chapter of this thesis respondents were required to make eleven best-worst judgements. The use of paired comparisons to generate equivalent data would have involved fifty-five judgement tasks.

Alternatively, best-worst choices could be inferred from an observed strict rank ordering of items. However, to model rank order data we must assume that all variability in judgements is due to inter-respondent differences. Since the Best-Worst scaling model allows for the existence of within-respondent judgement error it will be appropriate to use largest difference data inferred from a strict rank ordering of items only when such errors are negligible or are believed non-existent.

If the model is a good approximation to the experimentally derived data (and this can be validated with reference to the data itself) it may be used to interval scale items on the dimension(s) of managerial interest. Furthermore, the same data can be used to derive individual level 'difference -in-total' scales by subtracting the number of times an individual judges an item 'worst' from the number of times it is judged 'best'. Individual 'difference-in-total' scales or the best and worst choice totals from which they are derived can also be used as a basis for identifying relatively homogeneous subgroups and/or used to find important associations between item positions on particular dimensions.

Chapter IV: Review of Wood Quality Literature

Although the issue of wood quality has attracted far less research effort than have many other problems in forestry it has, nevertheless, inspired a substantial research endeavour. The breadth of the literature in this area reflects the complex, inter-disciplinary nature of the problem of actively managing the quality of forest resources for economic gain. Geneticists, wood scientists, forest managers, silviculturalists, engineers, wood processors, technologists, marketeers and economists have, to varying degrees, all contributed to the ongoing process of distilling an understanding of the physical and economic dimensions of the task. While this review is primarily concerned with the efforts of economists in this area, it attempts to establish their contribution within the broader context of wood quality research.

Of central importance to developing an appreciation of the issue of wood quality is the extensive body of literature which combines an understanding of the physiological foundations of wood production with the observed outcomes of numerous laboratory and operational trials to explore the relationship between key economic inputs - such as labour, capital, materials, time and expertise - and the quality and quantity of wood produced[37]. When read together, this literature describes the relationship between the levels of natural and human inputs to the wood growing process and the way in which volume and quality elated characteristics will be bundled together in forest crops. In other words, it describes the characteristic level production function for wood.

For some commercially important species information about treatment-response relationships has been formally incorporated into the structure of operational growth models or yield tables. The most sophisticated of these models describe a crop's response to the length of

---

[37] Bendtsen (1978, 1987), Briggs and Smith (1986), Nawitka (1987) and McKimmy (1986) provide useful reviews of this specialised and often technical literature. A summary of this literature was undertaken in Jennings (1989) and is not reproduced here.

time over which it is grown and to selected physical and economic inputs in terms of some or all of the following stand and tree characteristics: (i) total and merchantable volume (ii) basal area (iii) stems per hectare (iv) average tree height, and (iv) average tree diameter at breast height (dbh).

The relationship between the same set of management variables and other whole stem features (such as bole taper, ring width and knottiness) and basic wood properties (such as fibril angle and moisture content) is less well established. Despite widespread recognition of the potential importance of these effects, the mensuration and physiological basis for systematically incorporating a wider range of wood characteristics into growth predictions does not yet exist. Similarly, a short history of experience with some management activities - such as thinning, pruning and genetic selection - means that a crop's response, even in terms of traditional crop descriptors (such as total volume and number of stems), can not be accurately predicted. Consequently, operational wood production models are necessarily defined over incomplete sets of inputs and outputs.

The body of literature which establishes the links between these same basic resource characteristics as inputs to the forest products industry and the quantity and quality of end-products into which they, in combination with other non-wood inputs, are converted is of equal importance. This literature reports and synthesises the outcomes of experimental and operational mill conversion studies and provides the empirical substance of the characteristic level production relationship defined in equation 2.1[38].

This literature highlights a number of the complexities which characterize the wood quality management problem. First, it confirms that there may be a potentially large number of

---

[38] Survey articles by Briggs and Smith (1986), McKimmy (1986) and Kellog and Kennedy (1986) are a useful introduction to this literature. The summary of these articles is included in Jennings (1989) is not repeated here.

wood and tree attributes which influence product out-turn and quality. For example, Briggs and Smith (1986) compile a 'checklist' of twelve characteristics which are "frequently mentioned as having great impact on major wood products"; McKimmy (1986) adds a further five[39]. Second, both the direction and strength of a characteristic's influence depends on the particular end-use to which the resource is applied. Hence, while it is generally true that higher density wood displays greater stiffness and strength, high density may be undesirable for applications in which dimensional stability rather than strength is valued (Sutton, 1987). Thirdly, characteristic productivity for a given end-product depends on the specific technology employed. Hence, while it is generally true that higher density wood produces higher pulp yield and quality, low density wood is preferred for some pulping processes because of some desirable pulp characteristics (Sutton, 1987).

Although the research effort in this area has concentrated on the task of defining the physical relationships between input and output characteristics, several attempts have been made to predict the effect of changing wood quality on the economics of the forest product industry. For example, Kellog (1982) reports 'back-of-the-envelope' estimates of the cost, measured in terms of the reduction in the value of pulp and hem-fir structural lumber products to the British Columbian Coast of a 2 percent reduction in raw material density. He predicts that the change in feedstock would reduce the net value of pulp output by about $28.15 million each year and would decrease the value of machine stress graded hem-fir lumber by about $4.54 million per

---

[39] The list includes specific gravity, fibril angle, cell length, diameter and wall thickness, the percentages of juvenile and compression wood, knottiness, ring-width, bole taper, crookedness, the incidence of spiral grain, density uniformity, permeability, cross-grain and a number of within-annual ring micro-characteristics.

annum[40]. Smith and Briggs (1985) determine the dollar loss in lumber value for douglas-fir and hem-fir assuming progressively greater percentages of juvenile wood in processed lumber. Predicted losses reflect the effect on the grade distribution of output due to greater warpage and/or lower strength. Their results suggest that the value of lumber sawn from stems with a high juvenile wood component will be substantially discounted.

The economic link between (i) the production function for wood characteristics and, (ii) the production function for end-products, in which wood characteristics are arguments, is forged in the small number of specie specific models which are available to determine 'optimal' forest investments and forest tending regimes. For example, stand level growth models simulate individual tree and whole crop financial responses to various patterns of management, and use common programming algorithms to solve for wealth maximizing strategies (Heaps, 1985; Nawitka, 1987).

However, despite the increasing sophistication of these models, investment strategies still tend to favour forestry programs and management regimes which produce large volumes of fibre quickly. This is due to the fact that both growth models and revenue relationships continue to be defined primarily in terms of volume rather than characteristic space. In addition, in cases in which quality related premiums are embedded in revenue functions they reflect current, and not future, market conditions. Clearly, this acts to mask the influence that changes in technology, end-product demand and institutional constraints (such as log and product grading standards and codes governing end-use) will have on product revenue functions at rotation end. Hence, tools designed to analyze current investment decisions tend to ignore one of the key characteristics of the quality management problem, namely its unusually long-term nature.

---

[40] In the pulp industry this decline in value occurs due to the larger volume of wood input required per unit output. In contrast, the decline in value in the lumber industry reflects the poorer grade distribution of sawn output from a given volume of log input.

Sessions et al. (1986) provide an exception in that they use a stand level dynamic programming optimization package to examine the sensitivity of economically optimal management programs and financial profitability of changing characteristic premiums/penalties for Douglas-fir in the Pacific Northwest and loblolly pine in the South. In the case of loblolly pine, four scenarios incorporating various assumptions about acceptable utilization standards for both juvenile and fast grown wood (expressed as rings per inch) and changes in relative stumpage price levels were examined[41]. As expected, penalizing juvenile wood by restricting its use in sawtimber production resulted in a delayed, but heavier, second thinning and in an extended rotation. The final harvest consisted of fewer, larger stems which contained a reduced proportion of penalized juvenile wood. In response to a premium for the number of rings per inch (in the form of sawtimber grade utilization restrictions), the growth rate was moderated by leaving more stems standing at each thinning. The effect of increasing stumpage prices was to carry forward a larger growing stock so as to take advantage of higher future wood values.

Attempts to forecast the rate, or even direction, of changes in relative characteristic premiums are limited. Clearly, short term trends can be reasonably easily identified as premium structures associated with known product and process technologies will prevail. For example, the diffusion of thin curf saws and spindleless lathes will facilitate the use of small logs and reduce the existing relative advantage of large diameter logs. Similarly, processes are already available to overcome difficulties traditionally associated with the utilization of wood with a high incidence of defects such as knots, decay and stain. In the case of strength properties, defects may be randomized by laminating wafers or veneers or, alternatively, they may be cut out and a defect free product assembled by fingerjointing (Clarke, undated).

---

[41] For each scenario the thinning and final harvest schedule which maximized site expectation value for a given site index, initial stocking density and discount rate was calculated.

Identification of longer term trends is considerably more difficult and long term forecasts consist primarily of loosely tied conjectures. For example, Schuler and Meil (1989) draw upon a "knowledge of the relationship between technology, products and markets" to gain an appreciation of major changes likely to confront the Canadian woods products industry in the 21st century. Their conclusions suggest that the industry will be characterized by "resource neutral conversion and product technologies" which will emerge in response to "rising resource costs, lower resource quality and the need to convert manufacturing systems to more efficient, refined, uniform (pulverized) flow process".

The economic implications of changes in forest gene resources have also been studied. Typically, cost-benefit calculations of existing tree breeding programs have revealed economic gains for genetic improvements in crop volume (Lester, undated). For example, McKenny et al. (1989) examine the economic efficiency of a variety of black spruce tree improvement programs in Ontario. Genetic gains are modelled as a proportional increase in yield at all ages. In their analysis a 2000 hectare per annum seed orchard program results in a positive net benefit when seedlings are planted on high quality sites at a stumpage of $10.00 per cubic metre. A program of clonal breeding of similar size breaks even at a $50.00 per cubic metres stumpage. The effect on the economics of these programs of accounting for quality changes is unclear. On the one hand, faster growth rates associated with improved stock may result in less dense, more knotted wood which could reduce stumpage values. On the other hand, wood grown from stock bred in programs which select for both growth vigour and quality characteristics may earn a stumpage premium. McKenny et al. calculate that for a 1000 hectare planting program public investment in wood quality improvement programs would be economically justified only if improved wood were to receive a stumpage premium of at least $6.00 per cubic metre relative to wood from unimproved stands.

The most comprehensive effort to tie together the different strands of the wood quality research and literature in British Columbia is the Douglas-fir Task Force (Mitchell, 1988). Established by Forintek in 1986, the Task Force consisted of nine research projects that coordinated the efforts of a number of government and industry agencies and involved topics in wood physiology, processing performance and wood product properties. Because British Columbia has only a short history of applied silviculture, all of the projects had to draw basic data from trials conducted using selected trees taken from six naturally regenerated second-growth stands on Vancouver Island. The characteristics of these stands are thought to be representative of trees to be harvested from managed stands in the future.

The link between silvicultural treatment, wood properties, log quality, standing yield, product recovery and financial return is established in a suite of models known as SYLVER. SYLVER consists of a system of five interfaced models which together simulate the growth and impact of root rot on managed stands, cut and buck trees, configure a mill and saw logs to lumber, and calculate the net present value of growing, harvesting and processing the stand. The Task Force identified juvenile wood content, knots and log diameter as the major factors affecting lumber quality. Hence, TASS the biological growth and yield model was modified to provide information on juvenile wood content and branch diameter and boards were graded according to their juvenile/mature/clear wood content, their position in the tree of origin and its knot index.

SYLVER's strength, therefore, lies in its ability to capture some of the complex linkages between silvicultural treatment, wood attributes and product grade and to express these effects in terms of a familiar decision criterion, namely net present value. While the simulation framework does not try to value wood quality dimensions directly, their valuation is implicit in SYLVER's financial ranking of candidate treatments.

Economists interest in measuring the quality of goods is long standing. Two main

approaches to quality measurement have been developed - the index number approach and the hedonic approach[42]. Application of these methods to the measurement of historical changes in product quality in the forest products industry is both recent and limited. Brannman et al. (1981) and Puttock et al. (1990) use the hedonic approach to identify quality changes in stumpage sales while Jennings (1988) uses the same method to analyse the source of premiums and discounts for softwood dimension lumber. Constantino and Haley (1988) use the index number approach to construct historical wood quality indices for two Vancouver log markets and the Pacific Northwest, Westside, log market.

Brannman et al. (1981) estimated the hedonic price function for sales of Douglas-fir stumpage in the Pacific Northwest. Stumpage sales were characterized by measures of species mix, average forest-to-mill haul distance, the estimated length of road which needs to be constructed, the forest from which the sale originates, the yield of Douglas-fir per acre and the shares of various grades of saw and peeler logs in the sale. Coefficients of the hedonic price relationship were estimated using pooled, cross-section data on the price and characteristic rating of USFS timber sales, and information on changes in mean sale characteristics were used to decompose observed annual price changes into their quality induced and pure price change components. The authors found that the change in quality of Douglas-fir stumpage between 1968 and 1978 was not significantly different from zero but that year to year variations in the quality of stumpage sales were important.

More recently, Puttock et al. (1990) applied the hedonic methodology to data on prices

---

[42] The hedonic method was discussed in Chapter II. The index number approach to quality analysis is applicable when a good can be disaggregated into several discrete quality classes, such as log grades by species, each of which carries an identifiable price. Assuming that price accurately reflects quality, time series data on the grade distribution of total volume transacted and associated grade prices can be used to construct an index of the quality weighted volume. Since this index consists of an unweighted quantity and a quality component, deflating it by total unweighted volume yields an index of quality.

and characteristics of stumpage sales on private forest land in Southwestern Ontario[43]. Lump-sum stumpage sales were characterized by the following characteristics: total volume, the proportion of volume in each of three species groups, average volume per stem, haul distance to the purchasing mill and the quality of timber in the sale. Timber quality was expressed as a four point rating index where index values were linked both to categorical descriptors and to measurable criteria. For example, an index rating of '2' relates to a stumpage sale containing ten to fifteen percent by volume of Grades 1 and 2 sawtimber and is be considered to be 'good' quality. The results of this study suggest that timber quality significantly affects stumpage prices. The additional sale value attributable to a marginal improvement in timber quality is approximately $1,170. Evaluating stumpage at the sample mean for all sale characteristics, this represents a 12 percent increase in value[44].

Jennings (1988) uses data on mill door prices and lumber attributes to estimate implicit prices in the North American softwood lumber market for the period 1970 to 1986. Results indicate that the implicit price of an additional inch of dimension (or lumber width), which in a series of annual hedonic models ranged between zero and $10.60 per thousand board feet of lumber, became progressively more important during the study period. It is suggested that this reflects growing scarcity of logs from which large dimension lumber can be cut. Sales of lumber of uniform length commanded premium over random length sales, and significant premiums were paid for improvements in grade. Significant premiums for particular species were difficult to interpret since the study used mill-door, rather than delivered, lumber prices and the extent to

---

[43] Approximately 97 percent of productive forest land in the region is privately owned (Puttock et al., 1990).

[44] These results relate to a linear form of the hedonic price function. Unfortunately, the authors do not report quality price premiums on a volume basis. Furthermore, they do not address the possible correlation between a stands quality rating, its species composition and average stem volume.

which premiums reflect true quality differentials and the extent to which they reflect differences in average mill to market haul distances is unclear[45].

Constantino and Haley (1988) use the index number approach to document a decline in wood quality for the period 1925 to 1980 for the British Columbian Coast. A Tornqvist translog quality index was calculated using statutory log grade, species and expenditure data for the Vancouver Forest Region (VFR). The wood quality index declined during the 55 year period by nearly 25 percent or an average rate of -0.48 percent per annum. 58 percent of this decline is explained by changes in the species mix and 42 percent by changes in the grade distribution. Interestingly, the index declines at a declining rate over the period and actually increases during the interval 1971-1980. The latter observation reflects a strong positive species effect during this period.

Constantino and Haley also constructed quality indices for the three most important species in the VFR, namely western hemlock, Douglas-fir and western red cedar. Quality decline was marked for cedar and Douglas-fir but was negligible for hemlock, a species which only became commercially significant during the 1940's. In all three cases periodic sharp drops in quality have in part been offset by periods of rising quality.

Indices of quality change for logs traded on the Vancouver and Pacific Northwest log markets from 1957 to 1982 were also estimated. While the change in quality on the Vancouver log market was negligible over the period (.02 percent per annum), quality fell by about 0.42 percent per annum on the Pacific North-West log market. Furthermore, quality decline was

---

[45] For example, 99 percent of southern pine is consumed within the producing or adjacent regions, while significant volumes of S-P-F is shipped from Canada (all regions) to markets in the south of the United States. Similarly, an hedonic function estimated for Douglas-fir alone found shipments of British Columbian origin subject to significant discount vis a vis its United States counterpart, which may again be due different average transportation distance. This study also found that additional dimension was more valuable in douglas-fir lumber of British Columbian origin than in United States douglas-fir lumber.

completely due to a deterioration in the grade mix in the Pacific North-West while changes in species composition played a dominant role during periods of falling quality on the Vancouver log market.

Overall the analyses confirm the intuition that the quality of the wood supply on the British Columbian Coast has declined over time as the oldgrowth resource has been mined in sequence from best to worst. While the authors do not offer a generalized explanation for the occurrence of shorter periods of increasing wood quality they do suggest that the most recent period may reflect logging activity in very high quality oldgrowth stands in the Queen Charlotte Islands. Constantino and Haley conjecture that the trend will be toward more rapid and consistent declines in wood quality as expansions at the extensive margin of oldgrowth take logging into higher elevation, lower grade stands and there is a growing proportion of regrowth in the total wood supply. They suggest that British Columbia's trend in wood quality will then become more like that observed in the PNW log market where, already dominated by regrowth, changing wood quality reflects a decline in the mix of grades available.

Attempts to predict future log values, and by implication the structure of future quality premiums, are rare. Sterling Woods (1988) attempt to determine the changes in the value of tree stems which may result from changes in tree size, particularly diameter, which could be promoted through various silvicultural techniques. Expected future log, and by aggregation, whole stem price schedules were constructed for a range of species in the Coastal and Interior regions of British Columbia. Price schedules for the Coast were derived using VLM data for current sales of oldgrowth logs in grades which were assumed to have height and diameter characteristics similar to those expected in regrowth stands[46]. Consequently, implied future characteristic

---

[46] The implicit prices of stem length and diameter calculated using these data are reported in Chapter VII of this thesis.

premiums mirror the existing product mix and technologies. Log prices tend to rise rapidly through the lower diameter range (< 30 cm) reflecting improvements in recovery and product value in existing sawmills over this range. They then plateau until diameters reach the 40-50 cm range at which point expectations of clear product recovery fuels another strong upward price trend. The diameter classes applicable to second-growth stands lie mainly at the lower end of the range (10 -30 cm) where prices increase rapidly with additional diameter.

Sterling Woods also calculate the effect on Douglas-fir stem values which would result from specific increments to butt log value as a consequence of pruning to a height of 5.2 metres. For example, if pruning a 30 metre stem with a dbh of 35cm were to increase the value of the butt log by 45 percent, total stem value per cubic metre would be increased by about 20 percent from $38 to $45.

Attempts to harness the expertise of individuals directly involved in the forest sector to draw conclusions about wood quality requirements are becoming more common. For example, the Canadian Pulp and Paper Association (1988) questioned 68 individuals representing a range of research and operational organisations involved in the pulp and paper industry about the importance of a large number of growth, tree, wood, fibre, species, processing and pulp properties for the manufacture of bleached kraft and mechanical pulp. For each of 39 characteristics, respondents were asked (i) to indicate whether a 'poor', 'average' or 'good' level was preferred, and (ii) to rate the attributes importance on a scale from one ('low importance') to five ('high importance').

Results of the study consist of tabulations of aggregate preferences and importance ratings for both kraft and mechanical pulping processes. For example, 43 percent of respondents indicated that a 'poor' and an 'average' juvenile/mature wood ratio was preferred for kraft pulp manufacture. The remaining 14 percent preferred a 'good' level of this wood characteristic. The

mean importance rating of this attribute was 3.2.

The questionnaire also asked respondents to nominate (i) the four most preferred softwood species and (ii) the four 'most undesirable commonly available' species for both kraft and mechanical pulping. Again, results consisted of tabulations of aggregate preferences. Of the British Columbian species, members of the spruce, true fir and hemlock genera were the most frequently nominated 'preferred species', while members of the Douglas-fir, cedar and pine genera were the most frequently nominated 'undesirable available species'.

More informal attempts to promote the concept of forest crop planning, with an emphasis on the quality of the asset created, are not uncommon. A useful illustration is Rotherham and Hatton (undated) in which the individual viewpoints of 22 experts, from a variety of professional backgrounds, on forest crop planning are articulated in a series of technical essays and are informally synthesized by the authors in an executive summary.

Finally, application of the traditional methods of conjoint analysis to forest sector issues remain rare. Simpson (1986) uses a discrete choice conjoint model to establish the importance which forest managers and forest recreationalists place upon various aspects of forestland hunting experiences, such as accessibility and remoteness. More recently, Vertinsky et al. (1990) use conjoint analysis to determine priorities among a number of objectives that can be used to evaluate silvicultural investment opportunities in British Columbia. Objectives were arranged hierarchically and included such things as the provision of development opportunities, revenues, scenic beauty and a stable level of economic wood supply. Mean priority weightings were calculated for three constituencies; namely, the public (proxied by local government representatives), the Ministry of Forests and industry. Stated priorities proved to be broadly consistent across constituencies and showed surprisingly little variation in regional silvicultural priorities. Interestingly, all three groups placed the enhancement of wood supply quality amongst the highest ranked objectives.

Chapter V: Future Wood Quality Survey - Survey Description

A survey entitled "Coastal British Columbia - Future Wood Quality Survey" was distributed by mail to 154 individual residents of British Columbia during February of 1990[1]. The overall purpose of the survey was to investigate the nature and structure of demand for wood quality characteristics in Coastal British Columbia. More particularly, the survey was aimed at generating multiple characteristic judgement data which, in the absence of observable market data, could be used to construct empirical estimates of wood characteristic willingness-to-pay parameters and to formally depict the existing industries' consensus judgements. It has been argued earlier in this thesis that this information will improve our understanding of the way in which wood quality evaluations are formed and will provide useful empirical input into the forest crop planning process.

In this chapter both the survey procedure and instrument are described. A copy of the questionnaire and its supporting correspondence are included as Appendix I. The data collected via this questionnaire are analyzed and the results presented and interpreted in the following two chapters of this thesis.

Sample Selection and Survey Administration

Individuals who were invited to participate in the survey were chosen for their status as 'experts' in areas relating to Coastal forestry. It was assumed that 'experts' were capable of forming judgements both about the likelihood of future events occurring and about wood quality requirements. Experts were identified in either of two ways. Firstly, individuals were selected by virtue of their holding an 'expert position' in the forest sector. For example, it was assumed

---

[1] Six additional surveys were sent to individuals outside British Columbia. Their responses are not included in the analysis or discussion of results.

that an individual who occupied a position as the head of a key division within the Ministry of Forests or a major forest product company was capable of offering an expert opinion on the topic of wood quality and crop planning. Alternatively, individuals were selected upon recognition as an expert by a peer. Several individuals within the industry assisted with this task by recommending individuals to be included in the survey sample. All individuals selected in this way were recommended by at least two peers[2]. Care was taken to ensure representation within the sample across various occupational and employer groups. Limited pretesting of the questionnaire indicated a required response time of about 30-45 minutes.

Four measures were taken with the specific intent of encouraging a high rate of response to the questionnaire. First, a covering letter which accompanied the questionnaire (Appendix I(i)) stressed the importance of wood quality as an area of research and highlighted the contribution which expert judgement could make in promoting informed forest growing decisions. The reason for using repeated judgement experiments was also explained and the fact that there were no 'right' or 'wrong' answers to these types of experiments was stressed. Second, the option to remain anonymous was provided and confidentiality of individual level responses was guaranteed[3]. On the other hand, access to the results of aggregate level analysis was guaranteed[4]. Third, individuals were provided with a pre-addressed, postage-paid envelope in which to return their completed questionnaire. Finally, a reminder, in the form of a postcard, was sent to all individuals a week after the initial mailing of the questionnaire (Appendix I(iii)). This postcard re-iterated the importance of the research, thanked individuals who had already

---

[2] Many individuals were identified as experts by both methods.

[3] Twenty-two percent of respondents chose to respond anonymously.

[4] Sixty-five percent of respondents indicated an interest in receiving the results of aggregate level analysis, however many of these individuals also chose to remain anonymous.

responded and urged those who had not yet done so, to do so promptly.

Eighty-five individuals responded to the questionnaire over a period of approximately six weeks[5]. Of this number ten declined the invitation to participate in the survey[6]. This meant that seventy-five of the 154 individuals who were surveyed, or 49 percent, completed and returned questionnaires.

The questionnaire invited respondents to contribute comments about both the survey itself and the topic of wood quality. Space was provided throughout the questionnaire for this purpose. Forty-four individuals (or fifty-nine percent of respondents) declined to offer additional comment. Twenty-seven individual comments about the questionnaire itself were received. Twenty-four substantive comments about wood quality requirements in the Province were also received. Comments are reviewed at appropriate points in the analysis.

Survey Design

The questionnaire consisted of four distinct sections. In Section 1 of the questionnaire respondents were asked to provide basic information about the type of organisation they worked for, the nature of the work in which they were primarily involved and the length of their involvement in the forest sector. This information formed the basis of the occupational covariates which were used to partition the sample into occupationally homogeneous sub-groups and to explain individual differences in the judgement based responses elicited in subsequent sections

---

[5] This corresponds to fifty-five percent of the total sample. A three week response deadline was indicated in the questionnaire. This period proved unreasonably short and all responses, regardless of when they were received, were accepted.

[6] Seven individuals felt that they did not have the expertise required to answer the questionnaire, one was too busy, one found the questionnaire too difficult and one individual declined to participate on the basis of having retired from active participation in the forest industry.

of the questionnaire.

Figure V.1 summarizes respondent's occupational profiles[7]. Fifty-eight and forty-two percent of respondents were employed in the private and public sectors, respectively. Response rates by employer category are also shown. These range from a high of over eighty percent for University employees to a low of thirty-seven percent for individuals employed by a forest product company.

Respondents were distributed fairly evenly among the four occupational categories; namely research, operations, policy/planning and management/ administration/sales. Fifty-six percent of respondents indicated their primary field of work specialisation as either forestry/silviculture/genetics or wood processing. A further twenty percent indicated that they had no single field of specialization. Forty-six percent of respondents indicated that their work was related primarily to the forestry and logging sectors and seventeen percent to manufacturing. The remaining twenty-four percent of respondents stated that their work related to overall sectoral activity. All individuals had at least five years experience in the forest sector, with eighty percent claiming in excess of fifteen years service.

In Section 3 of the questionnaire respondents were asked to complete a task designed to empiricize their expectations of future technological, market and economic conditions. Responses to this section were used to cluster subjects in an attempt to identify sub-groups of the expert sample who were homogeneous in terms of their expectations and as covariates in the judgement based models of wood quality.

The task was structured as follows: respondents were presented with thirty brief

---

[7] Respondents were required to tick the category which corresponded most closely to their own circumstances. Where no named category was appropriate individuals indicated the category 'Other' and specified the nature of their affiliation/occupation. Completed questionnaires were checked manually and some categories redefined to maintain consistency across respondents. Figure V.1 is based on the redefined occupational covariate categories.

Figure V.1: Summary of Respondents' Occupational Profiles (n=75)

	Number	(Percent)	Response Rate (%)
Employer:			
Government (Provincial & Federal)	23	(31)	59
Forest Product Company	31	(42)	37
Industry or Professional Association/ Consultant	12	(16)	60
University	9	(11)	82
Total	75	(100)	49
Nature of Work in Which Primarily Involved:			
Research	22	(28)	
Operations	18	(24)	
Policy/Planning	19	(25)	
Management/Administration/Sales	17	(23)	
Total	75	(100)	
Primary Field of Work Specialisation:			
Forestry/Silviculture/Genetics	21	(28)	
Marketing/Economics	13	(17)	
Harvesting/Transportation/Engineering	5	(7)	
Wood Processing/Manufacturing	21	(28)	
No One Field of Specialisation	14	(19)	
Total	75	(100)	
Work Related Primarily To:			
Forestry/Logging	34	(46)	
Lumber	11	(15)	
Pulp/Paper/Composites	6	(8)	
Overall Industry Activity	24	(31)	
Total	75	(100)	
Number of Years Experience in Forest Sector:			
less than 5	0	(0)	
5 to 15	15	(20)	
greater then 15	60	(80)	
Total	75	(100)	

statements or propositions, each of which described a future state or event and each of which could be interpreted as having implications for future wood quality requirements in the Province. Respondents were asked to assign a probability of occurrence to each event or state. This probability was expressed by checking the appropriate box on a five category, discrete range probability scale. The high (probability equal to .8 to 1.00) and low (probability equal to 0 to .19) categories on the scale were labelled so as to correspond to events or states which would 'almost certainly' and would 'almost certainly not' occur, respectively. Respondents were asked to make their probability assessments on the basis of each statement being true in twenty years time[8]. Seventy-four individuals returned useable responses to this task.

Sections 2 and 4 of the questionnaire comprised independent repeated judgement experiments. The first of these experiments (Section 2) was designed to determine the weights which the sample of experts believed should be given to various commercial forest crop objectives in Provincial forest policy. The experiment generated largest-difference judgement data which was used to scale crop planning objectives using the Best-Worst scaling model described in Chapter III. Responses to this experiment were elicited prior to individuals being asked to formerly consider their expectations and without direct reference to future characteristic values[9].

The experiment was structured on the basis of an assumed hierarchy of objectives as depicted in Figure V.2. This implies that the overall commercial objective of crop planning is

---

[8] Clearly, wood available twenty years from now will come from existing regrowth forests. This means that several important aspects of individual tree and crop quality, such as species and location, have already been determined. However, it was felt that if confronted with a time horizon in excess of twenty years respondents would be either unable and/or unwilling to offer reasoned probability judgements.

[9] This assumes that individuals answered questions in the order in which they were presented with them.

Figure V.2: Assumed Hierarchy of Commercial Objectives for Provincial Crop Planning

A. Level-one objective

. *create a timber resource which will maximize the value of the Coastal forest product sector*

B. Level-two objective(s)

. *produce large volume of timber (measurable)*
. *produce high quality resource*
. *ensure low cost timber resource (measurable)*

C. Level-three objective(s)

. *produce high quality resource*

(i) large piece size (measurable)
(ii) good stem form (measurable)
(iii) low incidence of defects (measurable)
(iv) large volume of clearwood (measurable)
(v) narrow ring-width (measurable)
(vi) high mean wood density (measurable)
(vii) low within-stem density variability (measurable)
(viii) large volume of juvenile wood (measurable)
(ix) low between-stem characteristic variability (measurable)

Figure V.3: A Representative Comparison Set for Largest Difference Experiment

large piece size
good stem form
large volume of clearwood
low within-stem density variability
low between stem characteristic variability

to create a timber resource which maximizes the value of the provincial forest products sector. Level-two objectives can then be thought of as the means of achieving this overall objective. To be more precise, the commercial value of the wood using sector will be determined (at least in part) by the volume, quality and cost of the timber resource. In a similar way, level-three objectives are the measurable, and hence operational, characteristics associated with resource quality. This hierarchy is clearly partial in the sense that it includes only commercial aspects of forest management and excludes aspects of commercial value other than those related to the timber resource[10].

The experiment proceeded in two stages. First, respondents were presented with eleven comparison sets in which each of the nine quality related timber crop characteristics (or level-three objectives) was treated as a two-level factor (i.e., each characteristic was either 'present' or 'absent'). For example, the comparison set in which characteristics (i), (ii), (iv), (vii) and (ix) are present and characteristics (iii), (v), (vi) and (viii) are absent is shown below.

The comparison sets were constructed on the basis of an orthogonal, main effects fraction of a 2^{12} design (Appendix II(i))[11]. Respondents were asked to select i) the characteristic in each set which they believed should be given most weight in current provincial management and tree breeding decisions, and ii) the characteristic in each set which they believed should be given least weight, given that wood quality requirements sixty or so years hence are unknown. The task was organised such that subjects made both judgements simultaneously for each comparison set. This

---

[10] The goals of forest management extend well beyond maximizing commercial returns and include a range of environmental (e.g., habitat maintenance and watershed protection) and social (e.g., employment and community stability) objectives. In addition, commercial return depends on factors other than the characteristics of the fibre base.

[11] The twelfth set in this design was the null set. Characteristics appeared in the same order in each set. However, respondents were arbitrarily assigned one of three possible designs in which the order in which comparison sets appeared had been randomized.

should have helped in reducing judgemental errors and completion times for the task (Louviere and Woodworth, undated).

Seventy-four subjects returned useable responses to this exercise. Eight individuals commented on the difficulty of the most/least judgement task. Three particular reasons were cited. First, five of the eight individuals found maintaining consistency of judgements across comparison sets difficult[12]. Second, four individuals found the lack of explicit reference to either species or end-use problematic. Finally, five subjects indicated that their judgements had been confounded by their knowledge of existing characteristic correlations. By way of example, one individual noted the association between narrow ring-width and high mean wood density in the existing crop[13].

In the second stage of this experiment respondents were asked to rank the three two-level crop objectives - namely timber quality, volume and cost - in terms of the priority they believed that they should be given in current provincial silvicultural and tree improvement decisions. The purpose of this task was to establish metric scale priorities amongst level-two objectives. The rank-order data were used to generate individual level responses to an equivalent best-worst scaling task based on the three objectives using a 2^4 main effects design (Appendix II(i)). The

---

[12] One individual said that he had explicitly ranked the nine characteristics and referred to the ranking when making most-least judgements.

[13] Clearly there are numerous examples of environmentally correlated attributes within the existing timber crop. Often researchers will want to account for correlations such as these by either (i) using a Correlated Conjoint design (Louviere and Woodworth, 1987) or (ii) using factor analysis to develop orthogonal factor scores which are then used as measures of composite attributes. Existing colinearities were intentionally ignored in both experiments due to the fact that invited judgements were to be based on future market conditions. Hence, the potential exists for modifying inter-characteristic relationships via processes of silviculture, species selection and genetic improvement.

derived data were then used to estimate the aggregate scale values of a best-worst model[14]. Sixty-six respondents returned useable responses to the three object ranking task.

The purpose of the second repeated judgement experiment was twofold. Its primary purpose was to generate a set of scenario conditioned judgement data with which to estimate the parameters of a set of individual level conjoint equations of the form shown in equation 3.3. These parameters were then used to derive a series of input-price compensated characteristic value surfaces which effectively describe the underlying structure of characteristic demands.

The data were also used to investigate aggregate reactions to future wood profiles using the BDCM described in Chapter III. In a sense then, the model is used to identify the underlying 'statistical consensus' as to expected crop characteristic premiums among expert respondents and enabled the distribution of expert responses to profiles other than those presented to subjects in the experiment to be predicted.

Figure V.4: Timber Crop Characteristics used in Section 4 Experiment Design

Code	Characteristic
d1	*species*
d2	*average volume per stem*
d3	*average stem form*
d4	*incidence of defects*
d5	*incidence of clearwood*
d6	*incidence of juvenile wood*
d7	*mean wood density*
d8	*within-stem density variability*
d9	*between-stem characteristic variability*
d10	*total delivered fibre cost*

[14] Modeling the derived data as a best-least model assumes that respondents do not make any judgement errors when performing the underlying rank-order task. This assumption is reasonable in a task involving only three objects.

The experiment in Section 4 proceeded as follows. Respondents were presented with written profiles describing alternative crop types. They were asked to rate each profile on a metric measurement scale from zero to ten. The low and high points of the scale were anchored so as to correspond to 'very low (expected commercial) value' and 'very high (expected commercial) value', respectively. Profiles describing timber crop types were constructed by combining levels of the ten characteristics listed in Figure V.4. Nine characteristics (d1 to d9) describe the physical condition of the timber crop; the tenth (d10) relates to the cost of making the resource available. All characteristics were defined and modeled categorically[15]. Either two or four categories (or levels) of each characteristic were specified. A brief definition of characteristics and their levels was presented to subjects in the form of a chart. Subjects were encouraged to refer to the chart while completing the experiment (Appendix I(ii)).

Respondents were asked to reveal their profile valuations within an assumed context corresponding to expected ex post circumstances. More particularly, they were asked to base their assessments of timber resource values on their own expectations of future conditions as expressed in Section 3 of the questionnaire.

As the number of all possible combinations of the ten characteristics was too large for subjects to evaluate[16] a modified Hadamard design was used to select a subset of twenty timber type profiles (Appendix II(ii)). Use of these twenty profiles permitted the unconfounded estimation of the parameters of both the aggregate level BDCM and individual main-effects conjoint models. While use of a less restrictive plan would have permitted selected interaction

---

[15] In a number of cases characteristic categories were defined in terms of a permissible range of values of a corresponding continuous variable. For example, "high" average volume per stem referred to a resource where average stem volume fell in the range 2-3 m^3 roundwood.

[16] A full factorial design for this experiment would require subjects to assess $(2^7)(4^3) = 8888$ stimuli.

and/or higher-order effects to be estimated it would have substantially increased the number of stimuli in what was considered to be an already demanding experimental task[17]. Characteristics appeared in the same order in each profile. However, respondents were arbitrarily assigned one of three possible designs in which the order in which profiles appeared had been randomized.

Seventy-one individuals returned useable responses. Ten subjects commented on the difficulty of the rating task. As was the case in Section 2, three reasons were cited. First, three individuals indicated that they had found it difficult maintaining consistency across profiles. Second, two subjects found the lack of reference to a particular end-use problematic; and third, five of the ten subjects who offered additional comments indicated that their ability to rate some profiles was frustrated by the fact that they regarded them as being either 'unrealistic' or 'scarce in reality'. In particular, the designed orthogonality between the cost of timber and physical timber quality, and between stem volume and the availability of clearwood presented a conceptual problem to some subjects.

---

[17] The use of a logistic function in the BDCM meant that all characteristic interactions were implicitly included. However, the relative significance of these effects is not tested by the estimation procedure.

Chapter VI: Future Wood Quality Survey - Results and Analysis

The questionnaire described in Chapter V of this thesis elicited seventy-five completed responses over a six week period. The purpose of this chapter is to describe these responses and to present the results of estimating the analytical models discussed in Chapter III. Although a broad interpretation of results is given in this chapter, discussion of their policy implications and suggested directions for further research are reserved for the next, and final, chapter.

Scenario Conditioned Input-price Compensated Profit Surfaces

Chapter II of this thesis outlined the theoretical basis of the implicit market model and highlighted some of the limitations of applied implicit market analysis. The following chapter (Chapter III) argued that conjoint analysis, a well established experimentally based marketing technique, could be modified in order to provide empirical estimates of implicit market parameters. The procedure by which this could be done, which was described in Chapter III, suggested the need for two experimental components. The first component involves "conditioning" respondents with respect to their expectations of future circumstances. The second component requires individuals to reveal expectation conditioned valuation judgements over a designed set of multi-characteristic product profiles in which bundle price is included as a characteristic. These data are then used to estimate expected future price-compensated profit surfaces which, it was argued, mirror traditional implicit market bid functions. It was also noted that the influence of respondent's expectations on profit surface parameters could be explored.

The model was applied to an analysis of future wood markets in Coastal British Columbia. In presenting the results of this experiment attention is focused initially on the nature of expert expectations. Two aspects in particular are investigated. First, to what extent do experts agree on the nature of circumstances in which future wood transactions will occur? In

other words, is expert opinion characterized by consensus or fracture? Secondly, to what extent do individual attributes, such as employer and length of service, account for differences in expectational profiles?

Technological Expectations

Each individual's expectations of future market, technological and institutional conditions can be represented by a 30x1 vector (E). Each element of this vector (e_i) corresponds to the individual's assessment of the probability of event i occurring or state i eventuating[1]. When individual's response vectors were compared neither the hypothesis of equal response variance or of equal response mean could be rejected at the 95 percent level of significance. On the other hand, when response vectors were compared across statements, tests of both equal response variances and means were clearly rejected. Thus, taken as a group, respondents revealed significant differences in the probability with which they expected various events or changes occurring and in the variability of these expectations across statements.

Kendall's test of concordance is used to determine the relation between experts' response vectors (Siegel, 1956). Treating responses as ordinal probability rankings, Kendall's method tests to determine the strength of inter-subject agreement. The coefficient of concordance (W), which lies at the heart of the test, acts as an index of the divergence of the actual degree of agreement shown in the data from the maximum possible (or perfect) agreement, and is calculated as

$$W = \frac{s}{12k^2(N^3-N)} \tag{6.1}$$

where s is the sum of squares of the observed deviations of cumulative ranks from the mean

[1] Probabilities were expressed on a five-category, discrete range scale.

cumulative rank, k is the number of sets of rankings (i.e., the number of experts) and N is the number of entities (i.e. propositions) ranked[2].

Individual response vectors were first transformed to rank data by assigning tied observations the average of the ranks they would have been assigned had no ties occurred. In the presence of tied ranks Kendall's W should be corrected by subtracting $k\Sigma T_i$ from the denominator of equation 6.1, where $T_i = \Sigma(t^3-t)/12$. t is the number of observations in a group of ties within the ith ranking (Siegel,1956).

To test the significance of the calculated value of W we use the fact that $\chi^2 = k(N-1)W$ is approximately distributed as a chi-square with N-1 degrees of freedom. If the probability of obtaining a value at least as great as the observed χ^2 is "small enough", then the null hypothesis of no association between rankings can be rejected at that level of significance.

For N = 30 and k = 74 the null hypothesis of unrelated responses can be rejected at the .05 percent level of significance if the value of W exceeds approximately .02. A computed value of .34 means that we can reject the null hypothesis and conclude that the agreement among experts about proposition rankings is higher than would occur by chance[3].

In order to determine the extent of consensus about particular propositions, two additional summary measures of consensus were calculated. These are the measures of "relative entropy" (RE) and "unanimity" (U) (Kearl, 1979; Coleman, 1991). The two measures are calculated as follows.

---

[2] Therefore, W is the actual variance among the N sums of ranks (s), divided by the variance which would occur with perfect agreement among k rankings on N entities ($12k^2(N^3-N)$).

[3] However, this does not imply that observed rankings or orderings are 'correct'. Observed orderings are consensual, and may or may not be 'objective' or 'correct'.

$$RE = \sum_{i=1}^{30} (\pi_i \log \pi_i)/\log(1/n) \qquad (6.2)$$

and, $$U = \sum_{i=1}^{30} \pi_i^2 \qquad (6.3)$$

π_i is the proportion of respondents who give response i to a particular question and n is the number of possible responses.

The value of RE can range from zero to one. If there is complete unanimity in the response to a question RE will equal zero; if responses are spread equally across all response categories RE will be equal to one. RE measures the "sameness" of responses. Thus, a proposition which everyone agrees has a high probability of being true will have the same RE value as one which everyone agrees has a high probability of being false.

A proposition's U value measures the probability that two randomly selected experts would give the same response. U values may range from 1/n to one with higher values reflecting higher response consensus. For propositions with a U value greater than .5 we can say that it is more likely than not that two experts polled at random would have the same probability expectation.

Table VI.1.1 reports the entropy and unanimity values for the thirty experimental propositions. These results highlight the fact that the expert sample can be relied upon to agree on few things. For only three of the thirty propositions (#3, #19, #28) did the unanimity measure rank greater than .5[4]. The same three propositions also recorded the highest level of response

[4] Nearly one half of all propositions had unanimity measures which were less than .3.

Table VI.1.1: Summary Measures of Consensus by Question

Question #	Relative Entropy (RE)[a]	Unanimity (U)[b]
1	.981	.211
2	.667	.454
3	.491	.566
4	.769	.349
5	.847	.302
6	.659	.442
7	.656	.394
8	.850	.277
9	.924	.246
10	.912	.245
11	.865	.266
12	.668	.415
13	.887	.269
14	.784	.327
15	.871	.268
16	.872	.269
17	.885	.278
18	.603	.456
19	.541	.563
20	.786	.322
21	.915	.250
22	.884	.267
23	.823	.300
24	.810	.307
25	.836	.304
26	.901	.256
27	.905	.244
28	.475	.567
29	.855	.294
30	.703	.373

a. A higher value represents a broader range of opinion.
b. For n=5 the unanimity value lies between .2 to 1. A lower value represents a broader range of opinion.

"sameness" as measured by the RE index[5].

---

[5] This implies that there is quite strong agreement amongst respondents that our ability to sort wood and to allocate it to its highest value use will be greater than it is today, that there will be greater emphasis on end-product quality and precision in future markets and that less of the region's harvest will be exported as unprocessed logs.

The RE and U measures reported in Table VI.1.1 have been calculated maintaining the distinction between all five experimental probability response categories. If response categories are amalgamated then the two measures will obviously move towards displaying greater consensus. Specifically, if the two highest and two lowest probability categories are amalgamated, the number of questions in which unanimity ranks over .5 moves from three to fourteen (#'s 2, 3, 4, 5, 6, 7, 12, 14, 18, 19, 20, 23, 28, 30). While this gives a picture of more cohesion, it still leaves experts more likely to disagree than agree about the probability of occurrence for more than half of the propositions[6].

Based upon this weaker interpretation of consensus expert opinion suggests that the future industry will be characterized as follows:

Competitive advantage

. the region's competitive advantage will be in the production of specialty, non-standardised, high value-added forest products and not in the production of bulk, commodity-grade forest products.

. wood quality will continue to be an important source of this competitive advantage.

Product mix

. the product mix will be driven primarily by external market forces.

. unprocessed log exports will consume a reduced share of the region's wood supply.

. the manufacture of composite and/or reconstituted lumber/panel/board products and of CTMP will consume increased shares of the region's wood supply.

---

[6] Note that this profile of consensus beliefs is the same as would emerge from considering the order of the squared deviations of ranks associated with Kendall's coefficient of concordance. In other words, propositions which are identified as being characterized by greatest agreement using U and RE measures are the same as those which are ranked as either "most likely to occur" or "most likely not to occur" using Kendall's method.

Markets

. the emphasis on product quality and precision will be greater in these markets than it is in the markets in which the region competes today

. there will be a larger market for decorative and appearance grade wood products.

Technology

. the use of automated decision-making systems and optimizing, computerized scanning technologies in mills will be commonplace.

. increasingly, wood will be allocated to its highest value use as the ability to separate and sort wood improves

Other

. the export of unprocessed logs will be no less restricted than it is today.

. delivered wood costs will comprise an increased share of total production costs.

. environmental pressures will provide a central impetus to the development of wood saving and utilization improving methods.

Topics about which there was greatest dissent were the way in which chips and residues would be priced, the size of the flow of wood fibre transfered from the Interior to the Coast of British Columbia and the extent to which known products and processes will dominate the wood product sector in twenty years time[7].

The measures of consensus reported above have been applied across the entire expert panel. Although the results indicate divided opinion, it is possible that various subgroups of the panel exhibit significant similarities in terms of their expectations. These similarities were

---

[7] All three propositions had unanimity measures of less than .35. The minimum possible U value was .33.

explored in two ways. First, response proportions for various occupational cohorts were compared for each question using a series of X^2 tests[8]. The null hypothesis of equal response proportions across occupational cohorts was accepted for most propositions. However, there were a number of questions for which significant differences between the distribution of probabilities for various cohorts were identified. For example, public sector employees were more optimistic in their belief that the practice of separating mature from juvenile wood would become commonplace than were their private sector counterparts. On the other hand, private sector employees placed greater faith in the ability of continued technological change to accommodate declines in the quality of the wood resource.

The second way in which inter-respondent differences in expectations were explored was by attempting to cluster subjects on the basis of the similarity of their probability vectors. A single linkage cluster analysis resulted in chaining and failed to identify a non-trivial solution. For example, the two-cluster solution identified one cluster containing seventy-four individuals and one cluster of one individual.

Scenario Conditioned Input-price Compensated Profit Surfaces

Survey respondents were asked to perform two independent multi-characteristic judgement tasks[9]. The second of these experiments invited respondents to evaluate twenty designed timber crop profiles based on the premise that their expectations about future markets, technologies and institutional circumstances, as revealed in Section 3 of the questionnaire, were correct. Consequently, their product evaluations were to be 'conditioned' by expected future, rather than

---

[8] All tests were conducted using a 95 percent level of significance. Since there were five response categories the critical value of X^2 is 9.48.

[9] See Chapter V for a full description of these experiments.

perceived current, circumstances.

The data generated in this experiment consisted of seventy-one 20x1 vectors. Each element of a vector corresponded to an individual respondents rating of one of the twenty designed profile stimulus. The data were used to estimate individual level conjoint functions of the general form $R(z_1,\ldots,z_j,r)$, where $z_1,\ldots,z_j$ represent characteristic levels and r is unit price. Estimated coefficients were treated as approximations of the parameters of the profit function $\Pi(z_1,\ldots,z_j,r)$ and were used to derive individual level input-price compensated marginal bid functions for non-price input characteristics.

Results of estimating a main-effects only conjoint model are summarized in Table VI.1.2. Generally weak regression results suggest that the simple additive conjoint model did not provide an appropriate way of describing the majority of individuals' responses to design variables. In fact, a standard F-test of overall regression insignificance was rejected for only twenty-six of the seventy-one respondents (i.e., thirty-seven percent of the sample). Results were also characteristed by a small number of significant coefficients. However, nearly all significant coefficients were of the sign expected. Stem form, clearwood content and bundle price were significantly different from zero in the greatest number of individual equations. Nevertheless, main-effects explained over seventy percent of the variability in response data for all but two subjects and, provided the design does not confound main-effects with significant higher order interactions, estimated main-effects will not be biased (Louviere,1988a)[10].

Input-price compensated marginal bid surfaces for non-price input characteristics were

---

[10] Estimated coefficient vectors were treated as dependent variables in a MANOVA analysis of individual differences. The MANOVA analysis failed to identify any significant relationships between the four covarying individual respondent characteristics and regression coefficients. In addition, the analysis was able to identify only one significant paired characteristic correlation; namely, that attributing high importance to a high mean level of wood density was associated with attributing high importance to a low level of within-stem density variability. There was a notable absence of any discernible correlation between all other pairs of characteristics.

Table VI.1.2: Summary of Individual Main-Effects Conjoint Equation Estimation

Number of individual equations	71
Number of equations for which hypothesis of regression insignificance rejected[a]	26
Number of equations in which species significant[b]	9
average volume per stem	11
average stem form	19
incidence of defects	15
incidence of clearwood	20
incidence of juvenile wood	7
mean wood density	8
within-stem density variability	3
between-stem characteristic variability	6
total delivered fibre cost	24
R^2 (range)	(.61 - .99)
R^2-adjusted (range)	(-.05 - .99)
Mean value of dependent variable (range)	(2.4 - 6.4)

a. F-tests were conducted for a 5 percent significance level with a critical F-value of 4.64 for 14 and 5 degrees of freedom.

b. t-tests were conducted for a 5 percent significance level with a critical t-value of 2.57 for 5 degrees of freedom. To test the significance of four-level characteristics a likelihood ratio test ($\chi^{2*} = 11.07$) between the unrestricted model and models in which characteristic effects were restricted to zero were used.

calculated as follows. For any two-level characteristic i, the marginal bid for a change in characteristic content from level zero to level one ($MB_{0/1}$) is

$$MB_{0/1} = 2d_i/d_{price} \qquad (6.4)$$

where d_i and d_{price} are the estimated coefficents on characteristic i and price. For any four-level characteristic i, the marginal bids for changes in characteristic content are given by,

$$MB_{0/1} = 2(d_{i3}-d_{i2})/d_{price}$$

$$MB_{1/2} = 2(d_{i2}-d_{i1})/d_{price}$$

$$MB_{2/3} = 2d_{i1}/d_{price} \quad (6.5)$$

where d_{ij} is the jth estimated coefficient on characteristic i (j=1,2,3).

Marginal bids for a 'representative' individual are shown in Table VI.1.3 while sample

Table VI.1.3: Marginal Characteristic Bids for Respondent #58

Characteristic	Change in Level[a]	Bid (Can$/BDMT)
average stem form	0/1	95.20
incidence of defects	0/1	-121.50
incidence of clearwood	0/1	145.90
incidence of juvenile wood	0/1	-112.90
mean wood density	0/1	164.00
within-stem density variability	0/1	-37.00
between-stem density variability	0/1	-40.00
average stem volume	0/1	23.70
	1/2	47.20
	2/3	24.40
species	0/1	-14.80
	1/2	32.20
	2/3	24.20

a. Wood characteristic levels are as defined in the questionnaire 'Coastal British Columbia - Future Wood Quality Survey', Appendix 1(ii).

wide results are summarized in Table VI.1.4. Table VI.1.3 implies that respondent #58 would be willing to pay an additional $95/BDMT were the average stem form of wood fibre input improved from poor (substantial twist, lean, taper or twist) to good (minor or no twist, lean, taper or sweep). Negative estimated marginal characteristic bids indicate that the individual would only be willing to tolerate the specified change in characteristic content were input price reduced. For example, this individual would require a reduction of $121/BDMT in order to accept an increase in the incidence of defects from low (eg., 10% stem volume effected by conk, stain, fork, check, insect holes etc.) to high (eg., 30% stem volume effected by conk, stain, fork,

Table VI.1.4: Summary of Individual Marginal Characteristic Bids

Characteristic		Change in Level	Can$/BDMT
average stem form -	range	0/1	4697 (-) -787
	mean	0/1	130
	median	0/1	71
incidence of defects -	range	0/1	584 (-) -695
	mean	0/1	-59
	median	0/1	-46
incidence of clearwood-	range	0/1	3700 (-0 -981
	mean	0/1	124
	median	0/1	48
incidence of juvenile wood -	range	0/1	1370 (-) -1337
	mean	0/1	-32
	median	0/1	-21
mean wood density -	range	0/1	1856 (-) -451
	mean	0/1	72
	median	0/1	42
within-stem density variability -	range	0/1	590 (-) -1200
	mean	0/1	-34
	median	0/1	-17
between-stem density variability -	range	0/1	394 (-) -480
	mean	0/1	-22
	median	0/1	-20
average stem volume -	range	0/1	4435 (-) -3160
	mean	0/1	41
	median	0/1	5
	range	1/2	5040 (-) -1352
	mean	1/2	226
	median	1/2	102
	range	2/3	1755 (-) -2190
	mean	2/3	53
	median	2/3	4
species -	range	0/1	2335 (-) -2390
	mean	0/1	-20
	median	0/1	2
	range	1/2	3340 (-) -1635
	mean	1/2	-69
	median	1/2	-6
	range	2/3	1652 (-) -1520
	mean	2/3	74
	median	2/3	30

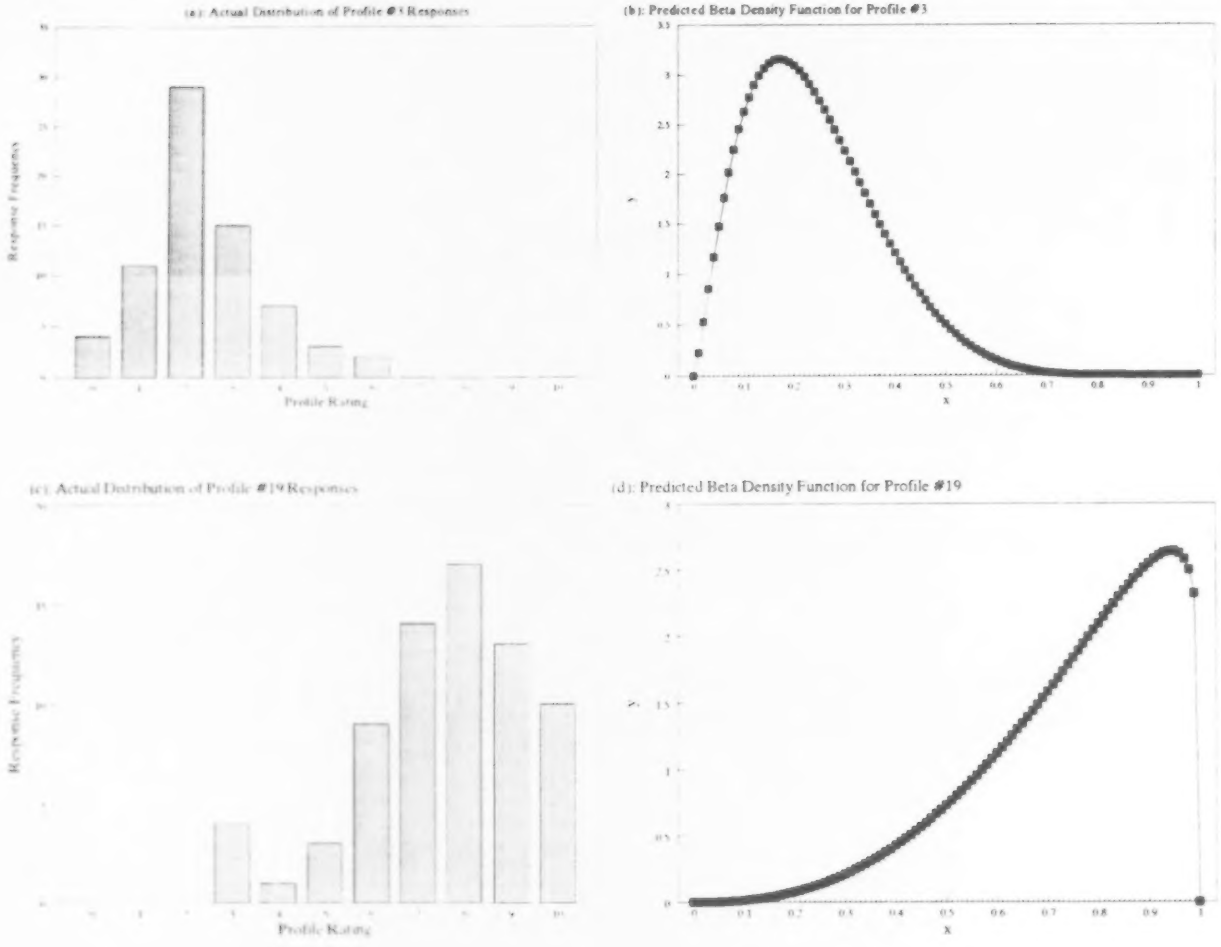
check, insect holes etc.).

Table VI.1.4 shows the mean, median and range of marginal characteristic bids for the entire sample. Excessively high ranges for all bids reflect the influence of the bids of three individual respondents. Given the effect of these outliers on the mean, median bids will better represent the samples' central tendancy. Generally weak conjoint results are reflected in a generally high calculated standard errors for marginal bids.

A Beta-Distributed Conjoint Model of Aggregate Crop Characteristic Value Perceptions

The previous section of this chapter drew upon the strength of conjoint design in order to generate individual level willingness-to-pay surfaces defined over characteristic, rather than whole product, space. While this blending of the applied methods of conjoint analysis with the theoretical construct of hedonics comprises the central focus of this thesis, the same data can usefully be employed to investigate the nature of, and forces behind, aggregate rather than individual level perceptions. Several approaches to the analysis of aggregate level conjoint data were discussed in Chapter III. One approach in particular, namely the beta-distributed conjoint model (BDCM), was described as a means of summarizing group perceptions over multi-characteristic profiles and of predicting group responses to changes in characteristic content. This section reports the results of estimating the BDCM for the response data elicited in section 4 of the questionnaire.

The first step in estimating the BDCM was to evaluate the first and second non-centralised moments (m_1 and m_2) of the distribution of responses for each experimental profile by computing the mean value of observed ratings and ratings squared, respectively. The parameters of the beta distribution of responses, α and β, were then calculated using the relationships described by Equations 3.6.1 and 3.6.2. Figures VI.2.1(a)-(d) show the close


(a): Actual Distribution of Profile #3 Responses
Response Frequency
Profile Rating
(b): Predicted Beta Density Function for Profile #3
X
(c): Actual Distribution of Profile #19 Responses
Response Frequency
Profile Rating
(d): Predicted Beta Density Function for Profile #19
X

Figures V1.2.1(a)-(d): Actual and Predicted Response Distributions for Selected Profiles

association between the distributions derived using the method of moments and the actual distribution of responses for two of the designed experimental profiles. Graphs (a) and (b) correspond to a crop description which is generally regarded as being of relatively low commercial value (Profile #3) while graphs (c) and (d) depict a profile which is generally more favoured (Profile #19).

There is no theoretical basis to the implicit assumption that a sample of conjoint responses must follow a beta distribution. However, the distributions' flexibility over a bounded interval makes it an obvious way to describe population heterogeneity in many human response behaviours and its use in a variety of social science applications have shown surprisingly good results (Rao and Zahoric, 1990). The use of the beta distribution as a model of response frequencies in this case was based initially on observed patterns in the data. All experimental distributions were observed to have shapes which could be captured by various values of the distribution parameters, α and β [11].

The appropriateness of using the beta distribution was confirmed by using a χ^2 test to assess whether or not the fit of the calculated beta density function to the empirical distribution is satisfactory. In other the words the calculated beta density function for each profile was integrated between successive pairs of interval boundaries to obtain expected interval proportions. Interval proportions were then used to calculate expected frequencies corresponding to the observed frequencies for those intervals. Calculating the value of χ^2 for each profile and comparing it with the .05 critical value of χ^2 substantiated the hypothesis that the data were obtained from sampling a beta distribution with parameters α and β equal to observed first and

---

[11] For various values of α and β the shape of the beta distribution may be uniform, triangular, bell-shaped, U-shaped, inverted U-shaped, J-shaped, reverse J-shaped or bi-modal, among others.

second distribution moments respectively, for all twenty experimental profiles[12].

In order to predict the distribution of responses to profiles which were not directly rated by subjects the functions g_1 and g_2 in Equation 3.7 must first be estimated. It is these equations which enable us to establish the relationship between profile characteristics and the parameters of the beta distribution[13]. Linear and logistic forms of g_1 and g_2 were estimated. Although both models performed well the later has an advantage in that it will not lead to predictions which lie outside the feasible range. The estimated coefficients and regression statistics of the logistic model are reported in Table VI.2.1[14].

A dominant feature of these results is the large number of significant coefficients and the

---

[12] The number of degrees of freedom for these tests was 8. This corresponds to the number of cells in the χ^2 test (11) less the number of estimated parameters upon which cell probabilities depend (2), less one (1). Hence, the .05 critical value of χ^2 is 15.507.

[13] The hypothesis that there were significant differences in the estimated parameters of the BDCM for the three subgroups receiving alternative designs was tested. The hypothesis was clearly rejected suggesting that order effects were unimportant.

[14] The following dummy variables were used to indicate characteristic levels for two- (j=3-9) and four-level (i=1,2,10) factors:

Characteristic Level	**Dummy Variable Values for Four-Level Characteristics di.1**	**di.2**	**di.3**
0	-1	-1	1
1	-1	1	-1
2	1	-1	-1
3	-1	-1	-1

Characteristic Level	**Dummy Variable Values for Two-Level Characteristics dj**
0	-1
1	1

Variables d1 to d10 correspond to the following characteristics; species, average volume per stem, average stem form, incidence of defects, incidence of clearwood, incidence of juvenile wood, mean wood density, within-stem density variability, between-stem characteristic variability and total delivered fibre cost.

Table VI.2.1: Regression of First and Second Moments of Responses on Characteristics

	Dependent Variable	
	m_1	m_2
Characteristics		
d1.1	-0.152*	-0.168*
	(-6.06)[a]	(-5.37)
d1.2	-0.188*	-0.251*
	(-7.46)	(-7.51)
d1.3	-0.104*	-0.143*
	(-4.16)	(-8.26)
d2.1	-0.003	0.026
	(-0.13)	(0.996)
d2.2	0.306*	0.427*
	(11.12)	(13.92)
d2.3	0.367*	0.457*
	(15.05)	(17.00)
d3	-0.234*	-0.293*
	(-13.21)	(-10.50)
d4	0.168*	0.239*
	(10.50)	(15.21)
d5	-0.244*	-0.333*
	(-12.42)	(-13.06)
d6	0.132*	0.188*
	(7.78)	(13.32)
d7	-0.100*	-0.145*
	(-5.48)	(-9.69)
d8	0.044	0.046
	(2.50)	(2.50)
d9	0.066*	0.081*
	(3.98)	(5.94)
d10.1	-0.051	-0.108
	(-1.92)	(-3.10)
d10.2	-0.234*	-0.328*
	(-8.52)	(-11.37)
d10.3	-0.260*	-0.383*
	(-9.40)	(-10.89)
constant	0.057	0.999*
	(1.29)	(20.58)
Log-Likelihood	56.48	68.12
R-Square[b]	.98	.97

* Denotes coefficients which are significantly different from zero at the 95% confidence level.

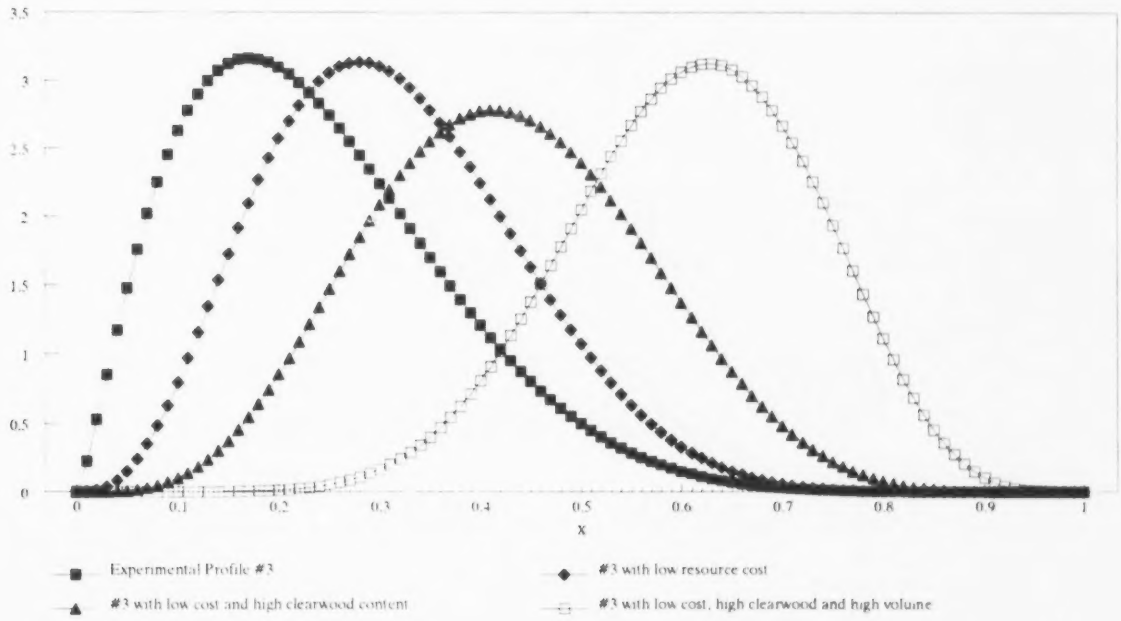
a. Figures in brackets are t-ratios.

b. R-square between predicted and observed values of m_1 and m_2.

very high R-square between the observed and the predicted values of the dependent variables. In fact, all variables, except for that associated with the level of within stem density variability (d8), are significant in explaining the first and second non-centralised moments of the distribution of expert responses[15].

Given these estimates it is possible to predict the distribution of expert ratings for crop

Figure VI.2.2: Predicted Beta Distribution for Profile #3 and Selected Improvements



profiles other than those evaluated by subjects. For example, Figure VI.2.2 shows the predicted

---

[15] For all variables associated with two-level characteristics (i.e., d3-d9) a t-test with $t^* = 3.18$ was used. To test the significance of four-level characteristics (i.e., di.1-di.3, i=1,2,10) a likelihood ratio test ($\chi^{2*} = 7.81$) between the unrestricted model and models in which di.1, di.2 and di.3, i=1,2,3, were restricted to zero was used.

response distributions for a sequence of profiles which correspond to successive improvements in experimental Profile #3. Shifts in the response surface illustrate increasing expert approval as (i) resource cost is lowered, (ii) clearwood content is enhanced, and (iii) stem volume is increased[16].

While this procedure provides predictions of parameters which completely characterize the response distribution for new profiles, estimates of m_1 and m_2 (or α and β) alone are difficult to interpret when not presented visually as done above. It was for this reason that Rao and Zahoric (1990) suggested using an alternative procedure in which the proportion of the expert population who have responses within a specified range is modelled directly as a function of the product's characteristics. Thus, the estimates of α and β derived above were used to compute the percent of beta distributed responses which fall above the mean population profile rating ($p=.44$) on the unit interval for each experimental profile (see Equation 3.8). Crop characteristics were then regressed on this variable which is referred to as CCDFBETA(.44,α,β). The results of both linear and logistic specifications are reported in Table VI.2.2.

The results suggest that variation in the proportion of favourable commercial expectations for experimental profiles is well explained by characteristic levels. All characteristics except for within-stem density variability (d9) are significantly non-zero at the 95% level in the logistic model[17]. Table VI.2.3 uses the estimated parameters of the linear BDCM to show how

---

[16] Unfortunately, no holdout profiles were included in the experiment. Had this been done, the predictive validity of the estimated models could have been formally explored. Nevertheless, the direction of all predicted effects have strong face validity. As always, however, care must be taken when predicting the response distributions for profiles which fall outside the range of experimental profiles used in the estimation. In other words, predicted distributions for profiles which are either 'better' or 'worse' than any experimental profile should be interpreted with caution.

[17] Neither within or between-stem characteristic variation or species are significant at the 95% significance level in the linear model.

Table VI.2.2: Regression of CCDFBETA(.44,α,β) on Characteristics

	Model (1) logistic	(2) linear
Characteristics		
d1.1	-0.176*	0.045*
	(-5.75)[a]	(3.24)
d1.2	-0.325*	0.062*
	(-13.62)	(-4.54)
d1.3	-0.164*	0.032
	(-7.84)	(-2.53)
d2.1	-0.100	0.042
	(-3.06)	(2.77)
d2.2	0.580*	-0.103*
	(18.39)	(-7.14)
d2.3	0.641*	-0.127*
	(23.01)	(-9.70)
d3	-0.475*	0.107*
	(-26.11)	(10.74)
d4	0.367*	-0.066*
	(19.86)	(-7.27)
d5	-0.563*	0.105*
	(-26.82)	(11.37)
d6	0.289*	-0.050*
	(15.73)	(-5.51)
d7	-0.227*	0.042*
	(-13.25)	(4.58)
d8	0.053	-0.022
	(2.97)	(-2.40)
d9	0.116*	-0.021
	(6.57)	(-2.31)
d10.1	-0.237*	0.029
	(-7.24)	(2.16)
d10.2	-0.538*	0.086*
	(-15.19)	(6.03)
d10.3	-0.647*	0.123*
	(-19.93)	(8.70)
constant	0.057	0.561*
	(1.29)	(21.39)
Log-Likelihood	56.48	68.12
R-Square[b]	.98	.97

* Denotes coefficients which are significantly different from zero at the 95% confidence level.
a Figures in brackets are t-ratios.
b R-square between predicted and observed values of ccdfbeta(.44,α,β).

Table VI.2.3: Contribution of Characteristic Levels to Proportion of Favourable Ratings

	Characteristic Levels			
Characteristic	0	1	2	3
Species (d1)	-.075	-.015	-.049	-.139
Volume* (d2)	-.060	-.018	.272	.188
Stem Form* (d3)	-.107	.107		
Defects* (d4)	.066	-.066		
Clearwood* (d5)	-.105	.105		
Juvenile Wood* (d6)	.050	-.050		
Mean Wood Density* (d7)	-.042	.042		
Within-stem Variation (d8)	.022	-.022		
Between-stem Variation (d9)	.021	-.021		
Delivered Cost* (d10)	.008	-.066	-.180	-.238

characteristic levels contribute to the proportion of favourable expert ratings[18]. Quantitatively, the dominant characteristics are average stem volume, stem form, the incidence of clearwood and the delivered cost of fibre. For example, improving stem form from level 0 (poor) to level 1 (good) would result in an increase in the proportion of favourable responses of over twenty percent. Similarly, raising average stem volume from level 1 to level 2 would result in nearly

[18] Estimates were checked to ensure that the model did not predict values of CCDFBETA(.44,α,β) outside the permissible 0-1 range.

thirty percent more favourable responses[19]. The inclusion of bundle price as a characteristic also enables us to investigate the tradeoff between physical characteristic content and a dollar metric. For example, improving the juvenile wood content of the crop would result in a net increase in the proportion of favourable expert approvals if it were associated with an increase in delivered fibre costs from 'very low' to 'low'. However, the same physical crop enhancement would result in a net reduction in the proportion of expert approvals if it were associated with a cost increase from 'low' to 'high'.

The choice of the overall mean rating as the critical value in the BDCM is arbitrary[20]. The model was also estimated for response cut-off values of .69 and .19[21]. Although the estimated parameters vary in magnitude across models the direction and relative importance of effects remained consistent.

Finally, profile characteristics were regressed on the standard deviation of responses around the mean as a proxy for the strength of consensus on profile ratings. In other words it was assumed that there was less disagreement among respondents about a profiles' expected commercial value the smaller was the standard deviation of responses. The standard deviation ranged from .12 to .33 on the unit interval. The results of this regression suggested that the strength of expert agreement was not well explained by crop characteristics. In fact, no single characteristic effect was significantly different from zero at the 95 percent level. The standard deviation was, however, quite strongly correlated with the mean profile rating, indicating that

---

[19] The predicted proportion of favourable responses to Profile #3 is .06. Predicted proportions corresponding to successive improvements depicted in Figure VI.2.2 are .17, .39 and .70, respectively.

[20] Rao and Zahoric (1990) use p=.8 as responses greater than this value correspond to what are known in the marketing literature as 'top box' scores.

[21] These values correspond to the mean population rating plus and minus the standard deviation of responses, respectively.

there may have been greater agreement among experts on the composition of generally favourable profiles than there was on the composition of generally unfavourable ones.

A Best-Worst Scaling Model of Expert Judgements over Provincial Forest Crop Planning Objectives

One of the objectives of this thesis was to formally identify the set of weights which experts believed should be ascribed to level-two and level-three objectives in the multiple objective hierarchy of forest crop planning objectives depicted in Figure V.2. This involves estimating the aggregate scale values for the sample of experts based on a MNL model of largest difference data in which planning objectives are represented as choice characteristics. Hence, the data, which was generated in Section 2 of the questionnaire, consists of individual most/least judgements for the set of designed comparison sets.

Data for each comparison set were cross-tabulated to obtain joint-frequencies of i) objective 'i' selected as most important and objective 'j' selected as least important, and ii) objective 'j' selected as most important and objective 'i' selected as least important for all pairs of objectives. Aggregate choice frequencies for all comparison sets were then pooled and maximum likelihood estimates of objective scale values of the MNL choice model in equation 3.14 of Chapter III were derived[22]. The results are shown in Table VI.3.1. The objective "low between-stem characteristic variability" was set to be the base or zero point of the scale.

Estimated scale values provide a basis upon which quality related crop planning objectives can be ordered from highest to lowest priority. Higher values in Table VI.3.1 represent more important attributes. Thus, producing a large volume of clearwood in the resource is perceived

[22] Estimates were derived using Foxlogit, a Fortran program written by Woodworth, G.G. and Gilbert, C. (1990), with extensions by Fox, M.F..

Table VI.3.1: Timber Quality Objective Scale Values Estimated from Most/Least Choice Data (n=74)[a]

Objective	Scale Value	Standard Error
large piece size	0.50	.106
good stem form	1.22	.108
low incidence of defects	1.22	.108
large volume of clearwood	1.40	.109
narrow ring-width	0.08	.102
high mean wood density	0.80	.107
low within stem variability	0.03	.104
small volume juvenile wood	0.46	.105
low between stem variability	0.00	-
Range	1.40	

a. Model χ^2: 410.17 with 8 degrees of freedom
Residual χ^2: 344.62 with 197 degrees of freedom

to be the most important crop planning objective and maintaining low between stem characteristic variability is regarded as least important.

Joint confidence intervals were constructed for each pair of objectives and the hypothesis that scale positions are equal was tested. The results of these pairwise tests, conducted for a 90 percent level of significance, suggested that objectives could be classified according to four statistically disjoint groupings or priority levels. For example, the three pairwise hypotheses of equal scale positions for objectives (ii), (iii) and (iv)[23] were all accepted at the 90% level of significance, while pairwise tests of equal positions between these objectives and all others were

[23] Objectives (i), (iii) and (iv) correspond to 'good stem form', 'low incidence of defects' and 'large volume of clearwood'.

rejected[24]. Priority groupings are shown in Figure VI.3.1.

Figure VI.3.1: Level-Three Objective Priority Groupings

Priority 1:	large volume of clearwood low incidence of defects good stem form
Priority 2:	high mean wood density
Priority 3:	large piece size low incidence of juvenile wood
Priority 4:	narrow ring width low within stem density variability low between stem characteristic variability

In Section 2 of the questionnaire individuals were also asked to rank the three level-two crop objectives - namely, timber quality, volume and cost - in terms of the priority they believed they should be given in current provincial silvicultural and tree improvement decisions. The distribution of responses across the six possible alternate rankings is shown in Table VI.3.2.

Sixty-two percent of respondents stated that they believed that timber resource quality should be afforded highest priority in provincial crop planning decisions. The remaining thirty-eight percent were divided almost equally between those who believed that the emphasis should

---

[24] As discussed in Chapter III, if respondent's repeated choices are not conditionally independent in different choice sets, standard errors associated with parameter estimates of the aggregate model will be biased downwards. An indication of this problem will be the existence of highly sub-significant residual chi-square values. Louviere and Woodworth (undated) suggest using adjusted standard errors obtained by multiplying estimated standard errors by the square root of the number of choice sets (i.e., 3.31). This corresponds to treating subjects as the units of analysis rather than the choice sets within subjects. Clearly, using adjusted standard errors in tests of parameter equality will result in the rejection of fewer pairwise attribute comparisons. If standard errors are too low, then the effective power of the test for significant objective groupings will be lower than is suggested here. No adjustment was made to standard errors due (i) to the models' highly significant residual chi-square and (ii) to the fact that the exercise was concerned primarily with the relative positioning of objectives and not with the absolute value of scale value estimates.

Table VI.3.2: Distribution of Level-Two Crop Planning Objective Rankings (N=66)

Ranking	Number of Respondents	Percent of Total
quality/volume/cost	13	19.7
quality/cost/volume	28	42.4
volume/quality/cost	9	13.6
volume/cost/quality	4	6.0
cost/quality/volume	5	7.7
cost/volume/quality	7	10.6
Total	66	100.0

be placed on achieving high timber volume and those who gave priority to maintaining a low cost resource. About one half and one third of the sample respectively placed timber volume and cost last in their ranking. Less than twenty percent afforded quality the lowest priority. Kendall's test of response concordance (Siegel, 1956) was used to test the hypothesis that experts rankings of the three objectives were unrelated to each other. This hypothesis was rejected convincingly, suggesting that agreement amongst experts was higher than would be by chance[25].

Objective rankings various employer and occupational groups were constructed and compared. The hypothesis of equal response proportions between groups was tested using a χ^2 test. The hypothesis of equal response proportions between government and private sector employees[26] was soundly accepted at the 95 percent level of significance. Similar tests between groups of experts involved primarily in research, operations, policy/planning, and administration/marketing/sales failed to detect significant differences in response proportions.

Individual level responses to a most-least scaling task using a 2^4 main effects design were

---

[25] The calculated value of W was .281, with an associated χ^2 value of 37.11 with 2 degrees of freedom. A χ^2 value of this magnitude has a probability of occurrence under the null hypothesis of unrelated rankings of less than .001.

[26] The two employer groupings consisted of 'Government (Provincial and Federal)' and 'University', and 'Forest Product Company' and 'Industry or Professional Association/ Consultant', respectively.

derived from the original rankings. Joint most-least response frequencies were cross-tabulated for the derived data and aggregate scale values for the three objectives were estimated using the MNL choice model and ML method. The objective of 'timber cost' was set to be the base or zero point of the scale. The results of this estimation are contained in Table VI.3.3.

Table VI.3.3: Timber Crop Planning Objective Scale Values Estimated From Most/Least Choice Data (N=66)[a]

Objective	Scale Value	Standard Error
Quality	0.49	0.095
Cost	0.00	-
Volume	-0.12	0.091

a. Model χ^2: 49.8 with 2 degrees of freedom
Residual χ^2: 12.85 with 6 degrees of freedom

Estimated positions show that respondents, as a group, believed that timber quality should be given higher weighting in provincial timber crop planning decisions than either timber cost and volume. There was no significant difference in the weighting implied for cost and volume. However, the hypotheses that the scale positions of quality and cost and quality and volume were rejected at the 95% level of significance. Consequently, the following level-two priority groupings are suggested (Figure VI.3.2).

Figure VI.3.2: Level-Two Objective Priority Groupings

Priority 1: timber quality

Priority 2: timber cost
timber volume

The level-three quality objective scale values reported in Table VI.3.1 reflect the most/least judgements of the entire sample of experts. Although these estimates are important,

since they capture the samples "average" beliefs, they mask the nature and strength of disagreement about objective priorities which exists amongst experts. Therefore, quality objective scale values were re-estimated for sub-groups of the expert sample using level-one objective orderings as a basis for clustering subjects. The results of these estimations are shown in Table VI.3.4. The objective "low between-stem characteristic variability' was set to be the zero point of the scale in all cases.

Table VI.3.4: Timber Quality Objective Scale Values Estimated for Expert Subgroups

	Level-two Objective Ranking[a]					
	q/v/c	q/c/v	v/q/c	v/c/q	c/q/v	c/v/q
Objective						
large piece size	1.04	0.34	0.66	1.05	0.66	-0.33
good stem form	1.84	1.36	1.07	1.47	1.23	0.28
low incidence of defects	1.76	1.42	0.99	0.98	1.60	0.52
large volume of clearwood	3.10	1.77	1.79	-1.00	0.82	-0.81
narrow ring-width	1.55	0.21	-0.75	-1.26	-1.11	-1.44
high mean wood density	1.61	0.76	0.68	0.87	0.18	-0.11
low within stem variability	0.17	0.17	-0.47	-0.20	0.19	-0.46
small volume juvenile wood	1.68	0.62	0.07	-0.44	-0.59	-0.74
low between stem variability	0.00	0.00	0.00	0.00	0.00	0.00
N	13	28	4	9	5	7
Range	3.10	1.77	2.29	2.73	2.71	1.96

a. 'q', 'v' and 'c' denote quality, volume and cost. Hence 'q/v/c' refers to individuals who ranked the three level-two objectives from most to least important as quality, volume and cost.

Estimated scale positions differed quite substantially and in intuitively predictable ways between sub-groups. Of particular note were the following observations;

(i) clearwood content was given the highest possible priority by both sub-groups for whom resource quality was most important. Furthermore, the relative advantage afforded clearwood was markedly higher for the group for whom cost was least important. On the other hand, this attribute was positioned eighth most important (of nine) by both sub-groups for whom quality was the least important crop objective.

(ii) ring-width was positioned as the least important attribute by all sub-groups for whom quality was not the most important objective. Furthermore, the more important resource cost was, the greater was the relative lack of advantage afforded ring-width.

(iii) between-stem variability was least important to both sub-groups for whom quality was most important. However, for those who believed that quality was least important and cost most important, uniformity was positioned as the third most important quality related attribute.

(iv) large piece size was important, occupying the second scale position, to the sub-group for whom quantity was the most important objective.

Finally, Multiple Correspondence Analysis was used to analyze associations between individuals' most and least totals. The number of times each objective was selected as i) most important and ii) least important were calculated for each individual. Correspondence analysis across individuals was performed on most and least totals separately and on aggregate most/least totals. The following linkages were suggested.

(i) individuals who gave a high rank to a low incidence of defects tended also to rank good stem form highly. There was a slightly weaker correspondence between this association and the tendency to favour the production of large volumes of clearwood.

(ii) favouring the production of small volumes of juvenile wood was associated with according narrow ring-width a high priority.

(iii) there was a strong positive correspondence between the priority given to low within-stem density variability and low between-stem characteristic variability.

(iv) the strongest linkage occurred between affording a low ranking to variability attributes and a high position to the production of clearwood.

(v) individuals who believed that piece size was important also believed that ring-width was unimportant.

Chapter VII: Discussion of Results and Conclusions

The imperative for viewing wood as a bundle of physical, biological and mechanical characteristics and for analyzing wood markets at the level of these characteristics, rather than as a tied bundle, was established in the first chapter of this thesis. Subsequent chapters emphasized the lack of empirical work in this area (Chapter IV) and identified a number of reasons why traditional methods of implicit market analysis were generally deficient when applied to wood markets (Chapter II). Chapter III suggested an alternative approach, whereby survey techniques, common in the area of market research, could be adapted to enhance our knowledge of the empirical structure of wood characteristic markets. The empirical component of this thesis centred around the analysis of results of a survey of future wood markets in Coastal British Columbia. The survey was described in Chapter V and the results of estimating a number of characteristic based models were reported in Chapter VI.

The final chapter of this thesis serves three purposes. The first purpose is to interpret the empirical results reported in the previous chapter. Results are interpreted in light of current forest management practices and their implications for forest policy reform are highlighted. However, this interpretation is qualified by a call for caution as a number of weaknesses in the empirical procedure and limitations of the approach are outlined. The second purpose of this chapter is to provide a brief discussion of the use of experimentally generated data in providing empirical information about implicit characteristic markets and to identify a range of other possible related applications. Finally, the chapter provides a conclusion to the thesis by highlighting its contributions, its strengths and weaknesses and by summarizing directions for further research.

The Policy Context

The unusually long production period involved in forestry means that current forest policy initiatives will have a strong influence on the nature of the future forest crop and, thereby, on future sectoral competitiveness and profitability. This influence may occur directly through policies which dictate the level and allocation of public and private sector forest management effort and silvicultural budgets on publically owned land. There may also be indirect influences which reflect the incentives which government policies exert over the private sector's husbandry of its own fee simple forest estate. In these ways, the current policy environment will, either unintentionally or by design, influence current actions and will determine the blueprint for subsequent industrial forest crops.

It is now generally accepted that wood resource quality, as well as volume and cost, should be considered in forest management and wood processing decisions. In an environment in which forests can be, and often are, managed for the production of quality related characteristics, and processing technologies adjusted in response to the nature of the fibre input, "competitiveness" may rely heavily upon the ability to match the nature of the resource with the technical requirements of end-use products. Effecting this match is not costless, and manipulating the supply of quality related characteristics embodied in future forest inventories requires current, and historically expensive, investment in silviculture and genetic research. On the other hand, while the demand for these same characteristics may be altered, technological research and development, and industrial retooling is also costly. In the past, forest investment analysis has accounted for differences in wood quality in modelling and simulation procedures which predict the influence of cultural technique on wood characteristics, product grade and, thereby, financial return. While the causality and physical interactions between forest management, log quality and product out-turn have been established at the characteristic level, the valuation of quality

characteristics has been done implicitly at the level of the final product.

Within this framework the effect of changing the supply of wood characteristics is examined by using alternate treatment/growth response relationships and by testing the sensitivity of value (or profitability) rankings to changes in product value/characteristic profiles. The impact of changes in processing technologies upon characteristic markets, or equivalently, in the relative demand price (or value in use) of different wood characteristics has rarely been \addressed. Sophisticated management aids, such as SYLVER, are capable of answering a broad range of "what if" questions. However, their focus upon end product markets as a source of derived wood quality valuation has tended to draw attention away from the interactions and dynamic forces which drive quality characteristic markets.

Calls for the development of a 'strategic approach' to timber supply in British Columbia in particular, and Canada in general, are now common (Government of Canada, 1989; Rotherham and Hatten, 1989; Lonnstedt et al., 1990). Lonnstedt et al. (1990) identify the existing lack of strategic thinking amongst both government agencies and the private sector as a constraint upon the British Columbian forest sectors' ability to meet the challenges posed by predicted short to medium term fibre deficits. Greater attention to "long term objectives, priorities, action plans and accountability" are required if the implications of the authors' "worst scenarios" are to be mitigated, if not avoided.

Rotherham and Hatten (1989) reiterate and strengthen these sentiments in their nation-wide summary of expert opinion about the importance of forest crop planning. There is little doubt that the ultimate litmus of sectoral competitiveness will continue to be performance in global markets, and that the high level of rivalry in these markets will mean that future directions will be largely governed by external forces. Nevertheless, the sectors ability to respond strategically to these pressures will in part be determined by our effectiveness in translating and

articulating shifts in product emphasis and process requirements into terms understood by forest managers and policymakers. If those responsible for tree improvement and silvicultural programs, both at the policy and operational levels, are to respond 'strategically' to the changing requirements of external markets then they must be provided with appropriate direction. Consequently, as argued by Rotherham and Hatten (1989), these groups must be furnished with information on " ... What products will be manufactured from logs harvested 40-60 years from now? What species should be grown? What should the wood and fibre characteristics of these trees be? ...".

Future Wood Characteristic Markets

The task of transfering forest investment and management decision analysis from goods space (where it has traditionally been conducted) to product characteristic space is complex. It requires a shift in the way we define products, categorize technological change and characterize agent behaviour and market interactions. Characteristic level analysis is now widespread in economics. However, despite the fact that the problem of "product design" with which forest managers and policymakers are confronted is conceptually no different from that faced by the producer of any quality differentiated product, applications in this field are novel. Two reasons for this have been identified. Firstly, the generally limited availability of market based price and characteristic data, upon which conventional implicit market models rely, bounds the useful extent of these methods. Secondly, the unusually long production period involved in forestry means that information embedded in observed market valuations of quality differentiated goods, while of interest, is of little value in signalling expected investment returns.

This thesis has suggested a new method of revealing information about the structure of characteristic markets. This approach preserves the "economic explanation" which underpins

traditional implicit market theory, while employing the empirical methods of conjoint analysis. While hedonics uncovers the structural parameters of characteristic markets by, in a sense, 'untying' the information contained in observed equilibrium market prices, this alternative approach attempts to predict market outcomes using information about agent behaviour revealed in experimental markets[1].

The main empirical component of this thesis involved applying this approach to the study of future wood characteristics in Coastal British Columbia. In particular, individuals' judgements (which had been 'conditioned' by their own beliefs about future market, technological and institutional conditions) about the expected value of designed multi-characteristic profiles were used to estimate individual level marginal bid surfaces for characteristics. The theory of implicit markets suggests that observed market clearing characteristic prices will be determined by the "matching" of buyers' marginal offer functions with the offer functions of sellers', or wood growers.

Results, based upon a main-effects only conjoint design, were summarized in Chapter VI. While the relatively small number of significant individual bids was disappointing, estimated effects were generally right-signed and of plausible magnitudes. However, the small number of significant bids mirrors the generally poor fit of the conjoint equations and demonstrates the inability of a simple main-effects specification to capture the nature of underlying preferences. In addition, although the simple conjoint model permitted non-linearities within characteristic bid surfaces, by assuming interactions to be zero it effectively constrains estimated bids to be identical across profit levels.

Results show that the demand for characteristics which are generally associated with solid

---

[1] This approach is developed and discussed in this thesis within the context of wood characteristic markets. However, it is clearly of more general applicability. Other possible uses and suggestions for further development are discussed later in this chapter.

wood products, such as piece size, clearwood content and defect content is expected to be stronger than is the demand for other characteristics. This is reflected in the larger number of significant individual marginal bids for these characteristics. Comparing the value of marginal bids with the expected marginal cost of characteristic supply will provide wood growers with an indication of whether or not particular crop treatments are likely to prove worthwhile. Overall, however, results display the diversity in individuals' expected marginal bid surfaces. While it is impossible to predict the precise nature of the future market equilibrium for any given characteristic, results suggest that it will be characterized by a spectrum of price and quality offerings. Consequently, expert judgements suggest that a market will exist for a range of characteristic levels and that future circumstances will not be best met by attempting to produce an undifferentiated crop. Unfortunately, little evidence was found to support the assumption that differences between individuals bids were explained by either respondents' demand related attributes (proxied here by their affiliation with the solid wood or fibre based processing sector) or their technological expectations.

The process of 'conditioning' respondents' rating judgements involved an additional exercise in which respondents were asked to reveal their beliefs about the probability of certain events occurring. This survey of expert beliefs about future conditions highlighted the existence of substantial discord in expectations. Although it appears that respondents used the probability rating scale in much the same way[2], they did not agree about the likelihood with which a large number of events would occur. In fact only three of thirty questions passed a strong test of response unanimity. This reflects the high degree of uncertainty which characterises change over such a long and volatile planning horizon and should further caution policymaker from adopting wood production strategies which might reduce their flexibility in meeting future challenges.

---

[2] The hypothesis of equal mean rating and variance was not rejected.

The overall "acceptability" of alternative crop characteristic profiles was explored by estimating the effect of characteristic levels on experts' aggregate response surface. This model, which assumed that responses conformed to a beta distribution, performed strongly. Results, which can be used to predict the "acceptability" of a range of possible future forest crops, confirm that expert opinion is most strongly influenced by the subset of solid wood product characteristics.

One of the secondary aims of this thesis was to identify a hierarchy of commercial forest crop planning objectives and to estimate a set of numerically scaled and testable objective weights. The lack of this information was identified earlier as a constraint on incorporating multiple and hierarchical crop planning objectives in decision making processes or in supporting models. Not only would this help to focus attention on the complex linkages between current action and future performance but it would provide a statistically rigorous basis upon which to weight multiple objectives when evaluating policies and/or when selecting between alternative courses of action.

A hierarchy of commercial crop planning objectives was identified in Chapter V and objective scale values, based upon the beliefs of the panel of forest management experts, were estimated and reported in Chapter VI. Largest difference data were modelled as a multi-nomial logit model in which crop planning objectives were represented as choice characteristics. Estimated parameters were then used to identify statistically distinct groupings of objective priorities. Sample wide aggregate priorities were depicted in Figures VI.3.1 and VI.3.2.

Results confirm the panel's belief in the importance of incorporating a consideration of resource quality in current forest policy. In fact, sample-wide results suggest that resource quality should be afforded a higher priority than either resource volume or cost. Furthermore, the incidence of clearwood and defects, and stem form were identified as the most important

determinants of resource quality. The least important determinants were perceived to be ring width and resource variability, both within and between stem. Overall, therefore, experts believe that emphasis should be placed upon policies which promote the production of well formed, defect-free clearwood stems. Policies which ensure these traits should, in turn, be afforded greater weight than those which reduce resource cost and promote the production of volume.

Although these results have statistical significance their practical robustness can be challenged on a number of counts. Firstly, sample-wide scale values reflect the statistically 'dominant' view amongst experts and effectively mask the existence of substantial 'minority' views. Although a majority of respondents (62 percent) nominated quality as the most important commercial crop attribute, nearly forty percent did not. In addition, scale values and, consequently, priority groupings for quality dimensions varied substantially across sub-groups of experts clustered on the basis of their higher-order objective rankings. For, example, while the volume of clearwood was ranked highest by those who considered quality to be the most important planning objective, it was placed last in the ranking by those for whom quality was least important. Clearly then, if true scale values are not the same across sub-groups, founding policy choices on priorities established on the basis of sample-wide choice data will falsely signal concord of opinion.

Furthermore, implicit in the most-least choice model is the assumption that all objectives are compensatory. In other words, trade-offs can be made in the sense that lower values on some objectives can be offset by higher values on others. Again this may veil the true nature of policy objectives. For example, some individuals may believe that a certain level of crop quality can not be compromised even if substantially lower costs and/or larger volumes can be obtained by pursuing some other policy. If this is the case, the decision-making process should account for constraints, aspiration levels and/or sequential attention to objectives.

Reliability and Validity of Results

A potentially serious problem with the empirical analysis presented in this thesis, which warrants separate attention, is the limited scope for formally testing the reliability and/or validity of results. While the "plausibility"[3] of results affords prima facie evidence of reliability and validity, no provision has been made to test the results. Tests of reliability, which may be carried out at either the level of respondent input judgement or at the level of estimated parameters, typically involve the use of repeated evaluations or of alternative forms (Green and Srinivasan, 1978)[4]. The process of alternative forms was not pursued, while the length of the original questionnaire rendered the process of repeated evaluations impractical. Respondents self-reports can also be useful in determining preference reliability. A number of respondents commented on the complexity and novelty of tasks involved and admitted having difficulty maintaining consistency in their responses.

Simple measures of goodness of fit are often relied upon to test the internal validity of results. Based upon these measures, aggregate models performed well and individual level models poorly, in this thesis. Internal validity can also be determined by using estimated preference parameters to predict preferences for a set of repeated or holdout stimulus. Correlating predicted and actual preferences provides a measure of cross-validation. Again, however, the size and complexity of the original questionnaire meant that the inclusion of holdout profiles in the design had to be sacrificed.

---

[3] Results are plausible if they reflect *a priori* expectations, based on prior theory or reasoning.

[4] The first approach requires respondents to repeat preference judgements over a subset of the original set of stimulus. These repeated evaluations can then be used in determining the test-retest reliability of the input preference judgements. The second approach asks a subset of respondents to evaluate a second set of stimulus, maintaining the same factor levels, at a later date. The equivalence of the estimated parameters from the two tasks can then be tested.

The external validity of a model based on experimental data can be tested by comparing its predicted behaviour against behaviour revealed in actual markets. Unfortunately, however, buyer preferences over wood characteristics in future markets are unobservable. Nevertheless, the current generation of forest managers' expectations of future wood quality requirements are implicitly revealed via their decisions on the level and nature of current silvicultural expenditures and research budgets. Attempting to validate experimental results by comparing estimated parameters with those implied by current actions implies that the objectives which dictate current actions are the same as those which underlie respondents experimental responses. Given the large number of financial, institutional and strategic factors which are likely to influence the observed allocation of resources, this assumption is unlikely to hold.

An alternative approach to external validation involves comparing model results with those obtained in analogous studies. Unfortunately, the literature reports no other attempts to either estimate the structural parameters of future wood characteristic markets or to quantify crop planning priority weights. Nevertheless, traditional hedonic analysis may be of use in highlighting whether main-effects models, as relied upon in this thesis, provide an appropriate representation of wood characteristic preferences.

Although future wood prices remain unknown, predicted future wood prices may be used as dependent variables in a first-stage hedonic estimation of expected equilibrium characteristic prices. Sterling Woods (1988) construct expected future log and, via aggregation, whole stem price schedules for a range of species in the Coastal and Interior regions of British Columbia. Price schedules for the Coast were derived using log market data for old-growth sales of logs in grades which were assumed to have height and diameter characteristics similar to those expected in regrowth stands. Hedonic, or marginal implicit, prices were derived from an estimated hedonic price function in which price per cubic metre was expressed as a quadratic function of

tree height (TH), dbh (DBH), and species Appendix (111). The results[5] suggest that both additional height and diameter in regrowth stems will continue to command price premiums for all species over the relevant range of stem dimensions[6]. Equal increments to stem height add equal value in all five species. Increasing stem height from 20 to 21 metres will increase the price by about $\$0.39/m^3$. However, the same height increment to a 30 metre stem would increase price by only $\$0.25/m^3$. Similarly, increasing the dbh of a douglas-fir stem with a 20 centimetre dbh will increase price by \$1.32/m3. However, a comparable change in the diameter of a cedar or balsam stem would increase price by \$1.58/m3 and \$1.02/m3, respectively.

Since hedonic results reflect equilibrium characteristic prices and embody information about current and not future demand and supply conditions they can not be used to externally validate experimental results. However, estimated hedonic results do suggest that interaction effects between characteristics may be statistically significant. If true, this would undermine the validity of relying upon main-effects models which effectively assume all interactions to be negligible.

---

[5] The following marginal implicit price equations were estimated. Reported equations include only those effects which are significant at the 5 percent level. SP, HEM, CED and BAL are dummy variables representing spruce, hemlock, cedar and balsam stems respectively. The suppressed species dummy represents douglas-fir. Figures in brackets are t-statistics and all prices are expressed in constant 1986 dollars.

Marginal Implicit Price of Tree Height (TH)

\$/m3 =	.67 -	.014(TH)
	(4.57)	(-3.2)

Marginal Implicit Price of DBH

\$/m3 =	1.96 -	.24(SP) -	.22(HEM) +	.26(CED) -	.30(BAL) -	.032(DBH)
	(21.92)	(-7.98)	(-7.35)	(8.7)	(-10.26)	(-15.02)

[6] Tree height was measured in meters and ranged from 20 to 40. DBH ranged from 20 to 50 centimetres.

Directions for Further Research

This thesis features a theoretical, an empirical, and an experimental component, each of which give rise to suggestions for further research. Firstly, the process of using individual's conjoint responses to reveal the structure of agent's marginal characteristic bid and offer functions may find wide application. While theoretically appealing, application of the hedonic model continues to be attended by a number of problems. Data availability is a recurrent constraint. Information on the prices and characteristic content of goods and services may be fragmented, or unreliable, or, as in the case of many heterogeneous environmental goods, non-existent. Even in cases where there is sufficient data to obtain first-stage hedonic estimates, there is frequently insufficient additional information on buyer and seller attributes available to perform a second-stage estimation and hence 'untangle' a set of supply and demand functions. The method suggested here relies on survey data, thus freeing hedonic analysis from its historical reliance on the observed outcomes of behaviour in actual markets[7]. This clearly expands the range of problems to which implicit market analysis can be applied.

Furthermore, as demonstrated in this thesis, the use of survey data enables the nature of characteristic supply, demand and equilibria to be explored over characteristic ranges which are not represented in current markets and under alternative technological and institutional circumstances. This can be expected to expand the predictive capabilities of implicit market analysis. In addition, although discussion in this thesis has been couched in terms of input characteristic markets, it is equally applicable to consumer good analysis. In these cases conditioning of individuals preference responses would be in terms of future socio-economic attributes (such as age, income and marital status) and the nature and availability of substitute

---

[7] While this is interpreted here as an advantage, analysis based on preference data which is revealed by agents in actual market transactions has the appeal of a certain prima facie validity which experimental data lacks.

and/or complimentary goods.

The empirical application in this thesis neither fully tested the process of linking hedonic and conjoint methods, nor provided the scope for establishing the accuracy of hedonic results based on multi-characteristic judgement data. A logical extension to this thesis, then, would be to apply the process within an empirical context which facilitated both of these tasks. These tasks would be best served by selecting an application involving a good with which respondents are familiar which can be completely characterized by a relatively small number of dimensions, each of which can be expressed as a continuous variable. Furthermore, in order to compare market parameters estimated using actual market transactions data and hypothetical responses, observed market data must conform to the requirements of traditional hedonic estimation procedures[8].

The empirical component of this thesis aimed at providing forest managers and policymakers with information concerning expected future wood quality requirements. In order to be of use, it was argued that this information must be defined at the characteristic, rather than the whole product level. While this aim has largely been met, results and, hence, conclusions must be heavily qualified. These qualifications indicate a number of areas in which additional research would both expand and improve upon information provided here.

Problems associated with model validation discussed in the previous section suggest that there is a clear need to investigate the markets for future wood quality characteristics using complimentary methodologies. All analysis presented in this thesis has been based directly upon subjective judgement data and intuitive forecasting procedures. The results of this approach need

---

[8] Dickie, Fisher and Gerking (1987) compare demand relations for fresh strawberries based on actual market transactions and hypothetical response data. In this way they were able to test the external validity of expressed preference data gathered in a contingent valuation survey against preferences revealed in an actual market situation. While their conclusions can not be extended to the analysis of characteristic market demand and supply relationships, the authers could not reject the null hypothesis of structurally identical demand equations obtained with these two data collection methods.

to be tested against those derived from models which rely on objective data and analytical forecasting techniques. In addition, approaches which explicitly model wood quality within the context of global forest products trade would enable explicit recognition of the behaviour of competing forest growing regions and of the strategic nature of the problem of product quality positioning.

The selection of the characteristic set in this exercise was done on the basis of a review of the technical wood quality literature and after consultation with individual experts. This process produced a relatively large set of nine determinant characteristics, all of which were included in choice set design. Consequently, in order to contain the size of the evaluative task, all characteristic interactions were assumed to be zero and main-effects only designs employed. Results suggest that the cost of this was incurred in terms of poor individual equation performance and in imposing the constraint of identical marginal bids across all profit levels. The seriousness of these implications suggest that further preliminary research into characteristic set design and the identification of significant interactions would improve both the reliability of data and model performance, and would assist in identifying correct functional forms.

The notion of consensus employed in this thesis has been one of statistical consensus. In many cases this consensus, which has been based on expert judgement, has been shown to be weak. For example, two experts polled at random would have a probability greater than 0.5 of agreeing on only ten percent of propositions. While this tells us that consensus in first-round judgements is generally low it also suggests the need to incorporate both iterative judgement procedures and feedback mechanisms in conjoint experiments of this type. By doing this, we would expect that the judgements of individuals with the weakest predictive ability would shift more towards the 'correct' answer than would those whose predictive skills are more accurate.

The empirical application in this thesis explored only the demand for wood

characteristics. An obvious extension to this work would be to establish the nature of analogous characteristic offer functions, thus enabling us to examine the nature of expected future implicit market equilibria. These functions reflect individual suppliers expectations of the cost of embedding additional amounts of characteristics in future crops and could be derived given a knowledge of expected treatment responses and costs.

Finally, this thesis relied exclusively on survey data in order to estimate the parameters of a standard economic model. To the extent that it attempted to examine economic phenomena and behaviour in a controlled setting it falls within the realm of 'experimental economics'. The testable question that then arises is the extent to which this exercise complied with the axioms of experimental economics as developed by Smith (1982)[9].

Conclusion

Many economic goods and services are traded according to a price per unit quantity (Leffler, 1982). Wood, for example, is sold by the cubic meter or tonne. When heterogeneous goods are priced in this way, the quantity characteristic (i.e, one, or one hundred, cubic meters) does not measure all of a goods economically important characteristics, and price per unit depends on the amount of unpriced characteristics contained. The price per cubic meter of wood, for example, may depend upon its species, density, ring-width and its clearwood content. Variants of the same good are said to differ in quality, "where quality refers to the amounts of the unpriced attributes contained in each unit of the priced attribute (Leffler, 1982)". Thus, while wood is sold according to the characteristic "wood volume", the quality of wood may refer to the proportion of clear to knotty wood volume.

---

[9] This would involve establishing the properties of nonsatiation, saliency, dominance, privacy, incentive compatibility and parallelism.

Although much economic analysis is conveniently and logically conducted at the level of priced characteristics, many practical problems are best addressed at the level of unpriced characteristics. In the case of wood, it is the occurrence of unpriced characteristics which determine its suitability for various end-uses, the quality of final products, production costs and, ultimately, profitability. Furthermore, silvicultural and genetic treatments show their effects in terms of both priced and unpriced resource characteristics.

Historically, little attention has been paid to the question of wood resource quality. This reflects a general lack of interest in crop planning as, until recent decades at least, the existence of substantial forest inventories has insulated managers and policymakers alike from the compelling incentives of scarcity. However, there is now universal acknowledgment of the need to both plan the establishment of forest crops and to incorporate priced and unpriced quality characteristics in these plans. In order for policymakers to formulate resource strategies, and for these to be implemented by forest managers, information about the characteristic markets in which these crops will be traded is essential.

The implicit, or hedonic, market model has provided economists with a well developed theory of characteristic markets and has been applied in a number of cases to explore empirical characteristic markets. While these applications have generally relied upon uncovering relationships implicit in actual market transactions, this thesis has attempted to construct a picture of future wood characteristic markets by inviting forest sector experts to reveal their economic evaluations in a hypothetical, design marketplace. In doing so, it has provided information about empirical wood characteristic markets, and has extended the usefulness of both the hedonic and conjoint approaches.

A reliance on survey data and subjective judgement in this thesis acts as a two-edged sword. On the one hand, results remain largely unvalidated and response reliability untested.

Consequently, empirical results, and hence policy implications, are heavily qualified. On the other hand, the survey process and instrument may have served to focus individuals thoughts and provided respondents with a forum within which to express their judgements. Responses highlighted the high level of fracture which exists amongst experts in terms of their opinions, expectations, beliefs and judgements on the issues of wood quality and crop planning. This points to the need for strategies which provide flexibility in the face of uncertain circumstances. Although this thesis has largely succeeded in serving its initial goals it has also highlighted a number of directions in which additional research is needed. For example, further empirical information about future wood quality requirements and characteristic markets is required, and alternative procedures for establishing these requirements need to be developed.

REFERENCES

Argarwal, M. K. and Ratchford, B. T. Estimating Demand Functions for Product Characteristics: The Case of Automobiles. Journal of Consumer Research 7: 249-262, 1980.

Barbour, R. J. and Kellog, R. M. Forest Management and End Product Quality: A Canadian Perspective. Forintek Canada Corp., Unpublished and undated.

Bartik, T. The Estimation of Demand Parameters in Hedonic Price Models. Journal of Political Economy 95(1):81-88, 1987.

Bendtsen, B. A. Properties of Wood from Improved and Intensively Managed Trees. in Impacts of the Changing Quality of Timber Resource, Porterfield, R. L. and Crist, J. B. (eds.), Forest Products Research Society, Wisconsin, Proceedings No. P-78-21: 26-37, 1978.

Bendtsen, B. A. Quality Impacts of the Changing Timber Resource on Solid Wood Products, in Managing and Marketing the Changing Timber Resource. White, J. L. (ed.). Forest products Research Society, Wisconsin: 44-57, 1987.

Boyer, A., Palda, K. S. and Ratchford, B. T. The Hedonic Approach to Price-Quantity Relationships and its Application to Marketing. Research in Marketing 7: 1-40, 1984.

Brannman, L., Buongiorno, J. and Fight, R. Quality Adjusted Price Indices for Douglas-fir Timber. Western Journal of Agricultural Economics 6(2): 259-272, 1981.

Briggs, D. G. and Smith, R. Effects of Silvicultural Practices on Wood Properties of Conifers: A Review, in Douglas-fir: Stand Management for the Future. Oliver, C. D., Hanley, D. P. and Johnson, J. A. (eds). College of Forest Resources, University of Washington: 108-117, 1986.

British Columbia. Ministry of Forests. Silviculture. Information Services Branch. 22p., 1983.

British Columbia. Ministry of Forests. Five Year Forest and Range Resource Program 1989-1994. 15p., 1989.

Brodie, et. al. ??????????

Canadian Pulp and Paper Association, CCPA Research Committee Questionnaire - Results. Unpublished, 1988.

Cattin, P. and Wittink, D. R. Commercial Use of Conjoint Analysis: A Survey. Journal of Marketing 46, 44-53, 1982.

Clarke, M. R., New Technology to Make New Products. Forest Crop Planning: A Corporate Approach to Strategic Planning of Forest Fibres, Trees and Stands to Meet Future Market Needs, Twenty-two Expert Views, Rotherham, T. and Hatton, J. V. (eds.). Contribution No. 16: 16.1-16.2, undated.

Coleman, W., Concord and Discord Amongst New Zealand Economists: The Results of An Opinion Survey. Department of Economics, University of Tasmania. Discussion Paper 1991-08, 27p., 1991.

Constantino, L. F. and Haley, D. Trends in Wood Quality for the British Columbia Coast and the United States, Pacific Northwest, Westside. Forest Science 34(1): 176-189, 1988.

Council of Forest Industries of British Columbia, The Vancouver Log Market: A Fair basis for Pricing B.C. Coastal Timber. Coast Forestry and Logging Sector, Presented to Deloitte Haskins and Sells, July 31, 1987.

Cubbage, F. and T. Harris, Jr. The Economics of Using Juvenile Wood for Southern Pine Products. Paper presented at the Forest Products Research Society, Southeastern Section Meeting, Nov. 6-7, 1986.

Currim, I. S., Weinberg, C. B. and Wittink, D. R. Design of Subscription Programs for a Performing Arts Series. Journal of Consumer Research 8: 67-75, 1981.

Dickie, M., Fisher, A. and Gerking, S. Market Transactions and Hypothetical Demand Data: A Comparative Study. Journal of the American Statistical Association 82: 69-75, 1987.

Epple, D. Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions. Journal of Political Economy 95(1): 59-79, 1987.

Globe and Mail. B.C. Researchers are Testing Cloning as a Way to Build Better Trees. November 27, 1989.

Goodman, A. C. Identifying Willingness-to-Pay for Heterogeneous Goods with Factorial Survey Methods. Journal of Environmental Economics and Management 16: 58-79, 1989.

Green, P. E. On the Design of Choice Experiments Involving Multifactor Alternatives. Journal of Consumer research 1:61-68, 1974.

Green, P. E. and Srinivasan, V. Conjoint Analysis in Consumer research: Issues and outlooks. Journal of Consumer Research 5: 103-123, 1978.

Griliches, Z. ed. Price Indexes and Quality Change. Cambridge, Mass.: Harvard University press, 1971.

Heaps, T. An Analysis of the Present Value of Stumpage Under a Variety of Economic and Management Conditions. Economic Council of Canada, Discussion Paper 284, 1985.

Hedayat, A. and Wallis, W. A., ??????????

Houthakker, H. S. Compensated Changes in Quantities and Qualities Consumed. Review of Economic Studies 3(19): 155-64, 1952.

Jennings, S. M. Hedonic Price Functions for Softwood Dimension Lumber. Unpublished, 1989.

Jennings, S. M. Valuing Wood Quality Characteristics: A Problem and Methodology Review. Forest Economics and Policy Analysis Research Unit. Working Paper 126, UBC. Vancouver, B.C. 55p, 1989.

Johnson, N. E. Concerns of the Forest Manager in Managing the Changing Forest Resource, in Managing and Marketing the Changing Timber Resource. White, J. L. (ed.). Forest products Research Society, Wisconsin: 84-90, 1987.

Kearl, J.R., Pope, C., Whiting, G. and Wimmer, L., A Confusion of Economists? American Economic Review, Papers and Proceedings 69, 75-79, 1979.

Kellog, R. M. Coming to Grips with Wood Quality. The Forestry Chronicle, December: 254-257, 1982.

Kellog, R. M. and Kennedy, R. W. Implications of Douglas-fir Wood Quality Relative to Practical End-Use, in Douglas-fir: Stand management for the Future. Oliver, C. D., Hanley, D. P. and Johnson, J. A. (eds). College of Forest Resources, University of Washington: 97-102, 1986.

Ladd, G. M. and Martin, M. B. Prices and Demands for Input Characteristics. American Journal of Agricultural Economics 58(1): 21-30, 1976.

Leffler, K. B. Ambiguous Changes in Product Quality. The American Economic Review 72(5): 956-967, 1982.

Leland H. Quality Choice and Competition. American Economic Review 67: 127-37, 1977.

Lester, D. T. Genetic Improvement. Forest Crop Planning: A Corporate Approach to Strategic Planning of Forest Fibres, Trees and Stands to Meet Future Market Needs, Twenty-two Expert Views, Rotherham, T. and Hatton, J. V. (eds.). Contribution No. 4: 4.1-4.2, undated.

Lonnstedt, L., Merkel, G., and Reed, F. L. C. The Outlook For Wood Fibre Supply in British Columbia: A Modelling Approach. Forest Economics and Policy Analysis Research Unit. Working Paper 153, 1990.

Louviere, J. L. and Gaeth, G. J. Decomposing the Determinants of Retail Facility Choice Using the Method of Hierarchical Information Integration: A Supermarket Illustration. Journal of Retailing 63(1), 25-47, 1987.

Louviere, J. J. Analyzing Decision Making; Metric Conjoint Analysis. Sage University Paper series on Quantitative Applications in the Social Sciences, 07-001. Beverly Hills: Sage Pubns., 1988(a).

Louviere, J. L. Conjoint Analysis Modelling of Stated Preferences. A Review of Theory, Methods, Recent Developments and External Validity. Journal of Transport Economics and Policy, January, 1988.

Louviere. J. L. and Horowitz, J. l. Comparing Models of Stated and Revealed Choices: Preliminary Findings from a Longitiudinal Study of U.S High School Students. Department of Marketing and Economic Analysis, University of Alberta, Working Paper Series 89-002: 29p., 1988.

Louviere, J. L. and Woodworth, G. On the Decision and Analysis of Correlated Conjoint Experiments using Difference Designs. Paper presented to the Annual meeting of the Association for Consumer Research, Boston, MA., 1987.

Louviere, J. L. and Woodworth, G. Best-Worst Scaling: A Model for Largest Difference Judgements.

McFadden, D. Conditional Logit Analysis of Qualitative Choice. In Zarembka, P. (ed). Frontiers in Econometrics. NY: Academic Press, 105-142, 1974.

McKenny, D. ??????????????

McKimmy, M. D. The Genetic Potential for Improving Wood Quality, in Douglas-fir: Stand Management for the Future. Oliver, C. D., Hanley. D. P. and Johnson, J. A. (eds). College of Forest Resources, University of Washington: 118-122, 1986.

Mitchell, K. J. SYLVER: Modelling the Impact of Silviculture on Yield, Lumber Value and Economic Return. The Forestry Chronicle, April 1988.

Nawitka Resources Consultants. Impact of Intensive Forest Practices on Net Stand values in British Columbia, Forest Resource Development Agreement, Canada/B.C. Report 014, 1987.

Nilsson, S. An Analysis of the British Columbia Forest Sector Around the Year 2000, Vol. 1. Forest Economics and Policy Analysis Research Unit. Information Report 85-1, 1985.

Poynton, R.J. Notes on Exotic Forest Trees in South Africa. Commonwealth Forestry Conference Australia and New Zealand. The Government Printer. Pretoria. South Africa, 135p., 1957.

Puttock, G.D., Prescott, D.M. and Meilke, K.D. Stumpage Prices in Southwestern Ontario: A Hedonic Function Approach. Forest Science 36(4): 1119-1132, 1990.

Rao, V. and Zahoric, A. An Application of the Beta Distribution in Aggregate Conjoint Analysis. Paper presented to the TIMS Marketing Science Conference, Durham, NC., March 1990.

Rosen, S. Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition. Journal of Political Economy 82(1): 34-55, 1974.

Rotherham, T. and Hatton, J. V. Executive Summary: Viewpoints on Forest Crop Planning. Forest Crop Planning: A Corporate Approach to Strategic Planning of Forest Fibres, Trees and Stands to Meet Future Market Needs, Twenty-two Expert Views, Rotherham, T. and Hatton, J. V. (ed). 6-10, undated.

Schuler and Meil, 1989. ??????????????

Sessions, J, Mann, J. W. and Brodie, J. D. Technical Advances in Wood Utilization, Quality Premiums for Stumpage, and Profitability of Forest Investment, in Assessing Timberland Investment Opportunities, Proceedings 47346, Forest Products Research Society, Madison, WI.: 45-52, 1986.

Simpson, R. An Application of Multinomial Logit Models and Functional Measurement to A Forestry Decision Problem. Unpublished term paper, Faculty of Business Studies, University of Alberta. 1986.

Smith, J. H. G. and Briggs, R. Juvenile Wood: Has it Come of Age?, in Juvenile Wood: What does it Mean to Forest Management and Forest Products? The Forest Products Research Society, Pacific Northwest Section, Proceeding 47309, 5-9, 1985.

Smith, V. L. Microeconomic Systems as an Experimental Science. American Economic Review 72: 923-55, 1982.

Sterling Wood Group Inc. Analysis of Changes in Timber Values Due to Silviculture Treatments Under the Canada-British Columbia Forest Resource Development Agreement. Forest Resource Development Agreement, Canada/B.C. Report 041, (ISSN 0835-0752), 1988.

Sutton, W. Review of the Radiata Pine Industry, in Managing and Marketing the Changing Timber Resource. White, J. L. (ed.). Forest Products Research Society, Wisconsin: 21-32, 1987.

Theil, H. Qualities, Prices and Budget Enquiries. Review of Economic Studies 3: 129-47, 1952.

Thorpe, T. A. Biotechnology: An Avenue to the New Forest. Forest Crop Planning: A Corporate Approach to Strategic Planning of Forest Fibres, Trees and Stands to Meet Future Market Needs, Twenty-two Expert Views, Rotherham, T. and Hatton, J. V. (eds.). Contribution No. 21: 21.1-21.3, undated.

Thurstone, L. L. A Law of Comparative Judgement. Psychological Review 34: 273-286, 1927.

Veeman, M. Hedonic price Functions for Wheat in the World Market: Implication for Canadian Wheat Export Strategy. Canadian Journal of Economics 35: , 1987.

Vertinsky, I., Wehrung, D. A.,and Brumelle, S. Priorities for Silviculture Investments: Public, Government and Industry Perspectives. Forest Economics and Policy Analysis Research Unit, University of British Columbia. Working Paper 147. 36p., 1990.

White, L. Quality Variation When Prices are Regulated. Bell Journal of Economics 3: 425-36, 1972.

White, L. Quality, Competition and Regulation: Evidence from the Airline Industry, in Regulating the Product, Caves, R. and Roberts, M. (eds), Cambridge, Ballinger, 1975.

Wilson, W. W. Hedonic Prices in the Malting Barley Market. Western Journal of Agricultural Economics 9(1): 29-40, 1984.

Witte, A. D., Sumka, H. J. and Erekson, O. H. An Estimate of A Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit markets. Econometrica 47: 1151-1173, 1979.

Woodbridge, Reed and Associates. Canada's Forest Industry, The Next Twenty Years: Prospects and Priorities, Volume 1: Stategic Analysis. Prepared for the Government of Canada; Canadian Forestry Services; Industry, Trade and Technology Directorate, Economics Branch. December 1988.

Woodworth, G. G. and Gilbert, C. LOGIT. Documentation for the LOGIT program to estimate Multinomial Logit Models with extensions by Fox, M. F. March 1990.

Appendix I: Coastal British Columbia - Future Wood Quality Survey

(i) Cover Letter

(ii) Questionnaire

(iii) Response Reminder

(i) Cover Letter

University of Alberta
Edmonton
Canada T6G 2H1

Department of Rural Economy
Faculty of Agriculture and Forestry
515 General Services Building, Telephone (403) 492-4225

January 29th, 1990

Dear ,

I am conducting a research project as part of my doctoral thesis in Forest Economics at the University of Alberta. This research has been discussed with, and is supported by, the Forest Economics Policy Analysis unit (FEPA) and the Council of Forest Industries (COFI). The purpose of my project is to identify (i) the determinants of wood quality, and (ii) how the nature of wood available in the future might affect the competitive position of British Columbia's Coastal forest products industry. Given the province's increasing reliance on regrowth forests and the potential for manipulating wood quality through forest management and genetic selection, my research is important and timely.

Since there is little data on this topic I will rely heavily on survey information. Because you are involved in, and familiar with, the forest industry I ask you to participate in my project by completing the enclosed survey. My survey determines the changes that you think will occur in the forest products industry during the next two decades, and how desirable you think a variety of different wood types would be as feedstock for mills in the future. Surveys like this are common in marketing research: producers are often interested in identifying which characteristics of their products consumers value most and are willing to pay premium prices for. Professionals like you who have completed my survey tell me it takes approximately forty minutes to complete.

Wood quality is now widely recognised as an important forest management and planning issue and my research offers you a way to express your opinions on this subject. Would you please complete the survey and return it to me in the envelope provided before February 19th, 1990. I guarantee confidentiality of your responses, and can make available to you the aggregate survey responses upon completion of my project.

I look forward to receiving your completed questionnaire. If you have any questions please contact me at (403) 492 5002.

Sincerely yours,

Sarah M. Jennings

Sarah Jennings
Ph.D. Student

(ii) Questionnaire

(ii) Questionnaire

Instructions

Thank you for agreeing to participate in my survey. The survey is designed to find out what characteristics of future timber resources you believe are going to be most valuable to Coastal British Columbia's forest product sector. There are no right or wrong answers to these questions. However, information about the beliefs and judgements of professionals like you will be useful in determining the type of wood quality at which provincial wood growers should aim and in highlighting aspects of tree improvement. Your responses to this survey will remain confidential, but you will be welcome to have a copy of the aggregate results when the study is completed.

The survey consists of the following four sections:

Section 1 asks for some very general background information about yourself and the type of work in which you are involved;

Section 2 asks for information about the type of timber crop you think British Columbia should be planning for, given that resources established today will not be harvested for at least 60 years.

Section 3 asks about changes you think are likely to occur in forest product markets, technologies and in general economic conditions during the next twenty years;

Section 4 asks you to evaluate different types of wood in terms of how valuable you think they would be to the forest product sector in twenty years time. (The survey includes a chart (last page) which describes the characteristics which are used to define wood of different types. Please tear this chart out and refer to these definitions as you answer Section 4 of the survey);

Please read the instructions at the beginning of each section carefully and ensure that you complete all questions. Also, feel free to make any comments about wood quality or the survey itself (space has been provided throughout the survey for your comments).

Thanks again for participating in my study.

****

SECTION 1

****

Personal information is needed in this survey so that I can determine whether an individuals' beliefs about change in the industry and about wood quality needs vary due to differences in who they work for and the sort of work they do. Your response to this survey will be strictly confidential.

Name (optional): _____

Employed by (check **one**):

[____] Provincial Government
[____] Federal Government
[____] Forest Product Company
[____] Industry Sponsored Association
[____] University
[____] Consulting Firm
[____] Other(please specify)_____

Nature of the work in which you are primarily involved (check **one**):

[____] Research
[____] Operations
[____] Policy/Planning
[____] Administration
[____] Other (please specify)_____

Primary field of work specialization (check **one**):

[____] Forest Management/Silviculture
[____] Marketing
[____] Harvesting/Transportation
[____] Economics
[____] Engineering
[____] Other (please specify)_____
[____] Biology/Genetics
[____] Technologist
[____] No One Field of Specialization

Work relates primarily to (check **one**):

[____] Forestry
[____] Lumber
[____] Pulp and Paper
[____] Plywood
[____] Other (please specify)_____
[____] Logging
[____] Overall Industry Activity

Years of experience in forest industry (check **one**):

[____] less then 5 years
[____] 5 - 15 years
[____] more than 15 years

SECTION 2

Many forest management and tree breeding decisions which are taken today will influence the type of timber available for harvest 60 years or more from now. Unfortunately, we do not know now what changes will occur during this period or how these changes will affect the industry's wood quality requirements. In this section I would like to find out what quality of timber crop you think British Columbia should be establishing in the Coastal region today, given that it will not be harvested for at least 60 years.

Below are 11 sets of quality related timber characteristics. For each set please indicate, by checking the space provided, which timber crop characteristic you think should be given most weight in current provincial management and breeding decisions and which you think should be given least weight.

Let's try an example:
Consider the five wood characteristics listed below. If you believe that, of these five characteristics, it is most important that British Columbia make species, silvicultural, and tree breeding decisions today which are expected to result in a Coastal timber resource which contains a small volume of juvenile wood and that it is least important that these decisions result in a timber resource which consists of large dimension stems you would respond, as shown below, by checking "e" and "a" respectively in the spaces provided.

	Most Important (check one)	**Least Important** (check one)
a. large piece size	___	✓
b. good stem form	___	___
c. narrow ring-width	___	___
d. high mean wood density	___	___
e. small volume of juvenile wood	✓	___

Now, please make this assessment for each of the 11 characteristic sets below:

	Most Important (check one)	**Least Important** (check one)
#1: a. good stem form	___	___
b. high mean wood density	___	___
c. low within-stem density variability	___	___
d. small volume of juvenile wood	___	___

	Most Important (check one)	**Least Important** (check one)
#2: a. large piece size	___	___
b. low incidence of defects	___	___
c. low within-stem density variability	___	___
d. small volume of juvenile wood	___	___
e. low between-stem characteristic variability	___	___

	Most Important (check one)	Least Important (check one)
#3: a. large piece size	____	____
b. good stem form	____	____
c. large volume of clearwood	____	____
d. small volume of juvenile wood	____	____
e. low between-stem characteristic variability	____	____

(1)

	Most Important (check one)	Least Important (check one)
#4 a. good stem form	____	____
b. low incidence of defects	____	____
c. narrow ring-width	____	____
d. low between-stem characteristic variability	____	____

	Most Important (check one)	Least Important (check one)
#5: a. large piece size	____	____
b. low incidence of defects	____	____
c. large volume of clearwood	____	____
d. high mean wood density	____	____

	Most Important (check one)	Least Important (check one)
#6: a. large piece size	____	____
b. good stem form	____	____
c. large volume of clearwood	____	____
d. narrow ring-width	____	____
e. low within-stem density variability	____	____

	Most Important (check one)	Least Important (check one)
#7: a. large piece size	____	____
b. good stem form	____	____
c. low incidence of defects	____	____
d. narrow ring-width	____	____
e. high mean wood density	____	____
f. small volume of juvenile wood	____	____

	Most Important (check one)	Least Important (check one)
#8: a. good stem form	____	____
b. low incidence of defects	____	____
c. large volume of clearwood	____	____
d. high mean wood density	____	____
e. low within-stem density variability	____	____
f. low between-stem characteristic variability	____	____

	Most Important (check one)	Least Important (check one)
#9: a. low incidence of defects	____	____
b. large volume of clearwood	____	____
c. narrow ring-width	____	____
d. low within-stem density variability	____	____
e. small volume of juvenile wood	____	____

	Most Important (check one)	Least Important (check one)
#10: a. large volume of clearwood	____	____
b. narrow ring-width	____	____
c. high mean wood density	____	____
d. small volume of juvenile wood	____	____
e. low between-stem characteristic variability	____	____

	Most Important (check one)	Least Important (check one)
#11: a. large piece size	____	____
b. narrow ring-width	____	____
c. high mean wood density	____	____
d. low within-stem density variability	____	____
e. low between-stem characteristic variability	____	____

In some cases growing timber of a particular quality will involve trading-off other timber crop objectives, such as the volume of timber produced and the cost of growing, harvesting and delivering the resource. Please indicate how you would rank these three objectives (i.e., 1st, 2nd or 3rd) in terms of the priority you think they should be given in determining current provincial silvicultural and tree improvement policies and actions.

	Ranking
high timber quality	____
large volume of timber	____
low wood cost	____

Comments (optional):

SECTION 3

The following questions are designed to identify changes that you believe will occur during the next twenty years in variables which could affect the type of wood quality required by British Columbia's Coastal forest product industry.

Please read each of the following statements and check the blank corresponding to the option which best reflects your own belief about the probability of the implied change occuring or of the statement being true.

Probability of Change Occuring or of Statement being True in Twenty Years Time

	0 -.19 (almost certainly will not occur or be true)	**.2 -.39**	**.4 -.59**	**.6 -.79**	**.8 -1.00** (almost certainly will occur or be true)	
The practice of separating mature from juvenile wood prior to or during processing will be widespread	[___]	[___]	[___]	[___]	[___]	(check one)
There will be fewer restrictions on the export of unprocessed timber than there are today	[___]	[___]	[___]	[___]	[___]	(check one)
The ability to sort wood and to allocate it to its highest value use will be greater than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
The absolute size of the world market for decorative and/or appearance-grade wood products will be smaller than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
The Coastal region's competitive advantage will be in the production of bulk, commodity-grade forest products	[___]	[___]	[___]	[___]	[___]	(check one)
Environmental pressures will result in more intensive wood utilization and will promote changes which improve wood recovery	[___]	[___]	[___]	[___]	[___]	(check one)
The region's timber resource will continue to be an important source of competitive advantage to the Coastal forest product industry	[___]	[___]	[___]	[___]	[___]	(check one)
Technological change and the development of new products will accomodate any changes in the quality of the wood resource	[___]	[___]	[___]	[___]	[___]	(check one)
The flow of wood fibre from the Interior to the Coast in British Columbia will be larger than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
Harvesting and transportation costs will comprise a larger share of delivered wood costs than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)
Delivered wood costs will comprise a smaller share of total pulp and paper production costs than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)

Probability of Change Occuring or of Statement being True in Twenty Years Time

	0 -.19 (almost certainly will not occur or be true)	.2 -.39	.4 -.59	.6 -.79	.8 -1.00 (almost certainly will occur or be true)	
The share of the region's wood supply used in the manufacture of composite and/or reconstituted lumber/panel/board products will be higher than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
"Engineered" wood products will compete successfully against solid-wood products in decorative and/or appearance-grade product markets	[___]	[___]	[___]	[___]	[___]	(check one)
The Coast's competitive advantage will be in the production of specialty, non-standardized, high value-added forest products	[___]	[___]	[___]	[___]	[___]	(check one)
Virgin wood fibre will become increasingly expensive relative to recycled wood fibre and other non-wood fibre substitutes	[___]	[___]	[___]	[___]	[___]	(check one)
The share of the region's wood supply used in the manufacture of bleached kraft pulp will be higher than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
Average mill capacity in the wood product sector will be larger than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
The use of automated decision-making systems and optimizing, computerized scanning technologies in Coastal wood product mills will become commonplace	[___]	[___]	[___]	[___]	[___]	(check one)
A higher proportion of the Coast's timber harvest will be exported as unprocessed logs than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)
The Coast's product mix will be determined primarily by external market forces	[___]	[___]	[___]	[___]	[___]	(check one)
Chips and other residuals will be priced as roundwood	[___]	[___]	[___]	[___]	[___]	(check one)
The Coast's pulp and paper sector will rely more on the use of roundwood and less on residuals than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)
Delivered wood costs will comprise a smaller share of total lumber/panel production costs than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)

Probability of Change Occuring or of Statement being True in Twenty Years Time

	0 -.19 (almost certainly will not occur or be true)	.2 -.39	.4 -.59	.6 -.79	.8 -1.00 (almost certainly will occur or be true)	
The pulp and paper sector will be dominated by products and processes which are already known today	[___]	[___]	[___]	[___]	[___]	(check one)
The share of the region's wood supply used in the manufacture of solid-wood products will be larger than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
The Coast's hardwood resource will be used extensively as feedstock for pulp production	[___]	[___]	[___]	[___]	[___]	(check one)
Average mill capacity in the pulp and paper sector will be larger than it is today	[___]	[___]	[___]	[___]	[___]	(check one)
End-product quality and precision will be more important in the markets in which the region competes than is the case today	[___]	[___]	[___]	[___]	[___]	(check one)
The wood product sector will be dominated by products and processes which are already known today	[___]	[___]	[___]	[___]	[___]	(check one)
The share of the region's wood supply used in the manufacture of CTMP will be larger than it is today	[___]	[___]	[___]	[___]	[___]	(check one)

Comments (optional):

SECTION 4

Please assume that the changes you indicated that you believed would occur in the next two decades in the previous section, in fact, are realized. Now, for each of the twenty (20) timber types described below, please circle one (and only one) number on the rating scale provided to indicate how valuable you expect wood of the type described would be as feedstock to this industry. You will find it necessary to refer to the characteristic definitions given in the chart provided on the last page of the survey as you do this. Please tear this chart out and familiarize yourself with it before answering this section.

Let's try an example:
Consider wood of the type described below. If you believe that wood of this type would be of low commercial value then you might mark the rating scale provided by circling the number 3 as shown below.

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**low**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**high**

0 1 2 (3) 4 5 6 7 8 9 10

very low value — very high value

Now, refering to characteristic definitions given in the chart provided please rate each of the following timber types according to their expected commercial value.

#1:

Species:	**Coastal Balsam**
Average Volume per Stem:	**very low**
Average Stem Form:	**poor**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**high**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#2:

Species:	**Coastal Balsam**
Average Volume per Stem:	**low**
Average Stem Form:	**good**
Incidence of Defects:	**low**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**low**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#3:

Species:	**Coastal Western Hemlock**
Average Volume per Stem:	**high**
Average Stem Form:	**poor**
Incidence of Defects:	**low**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**very low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#4:

Species:	**Coastal Balsam**
Average Volume per Stem:	**high**
Average Stem Form:	**poor**
Incidence of Defects:	**low**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**high**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**very low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#5:

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**low**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**high**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#6:

Species:	**Coastal Western Red Cedar**
Average Volume per Stem:	**high**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#7:

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**high**
Average Stem Form:	**poor**
Incidence of Defects:	**high**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**very high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#8:

Species:	**Coastal Western Red Cedar**
Average Volume per Stem:	**very high**
Average Stem Form:	**good**
Incidence of Defects:	**low**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**high**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**very high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#9:

Species:	**Coastal Western Red Cedar**
Average Volume per Stem:	**low**
Average Stem Form:	**poor**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**low**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**very low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#10:

Species:	**Coastal Balsam**
Average Volume per Stem:	**very high**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**high**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**very high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#11:

Species:	**Coastal Balsam**
Average Volume per Stem:	**very high**
Average Stem Form:	**poor**
Incidence of Defects:	**high**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#12:

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**very low**
Average Stem Form:	**poor**
Incidence of Defects:	**low**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**very high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#13:

Species:	**Coastal Western Red Cedar**
Average Volume per Stem:	**very low**
Average Stem Form:	**good**
Incidence of Defects:	**low**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#14:

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**high**
Average Stem Form:	**poor**
Incidence of Defects:	**high**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**high**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#15:

Species:	**Coastal Western Hemlock**
Average Volume per Stem:	**very high**
Average Stem Form:	**good**
Incidence of Defects:	**low**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#16:

Species:	**Coastal Western Hemlock**
Average Volume per Stem:	**low**
Average Stem Form:	**poor**
Incidence of Defects:	**low**
Incidence of Clearwood:	**at least one merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**high**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#17:

Species:	**Coastal Western Hemlock**
Average Volume per Stem:	**very low**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**low**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**very high**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#18:

Species:	**Coastal Douglas-fir**
Average Volume per Stem:	**very high**
Average Stem Form:	**good**
Incidence of Defects:	**low**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**high**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**very low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#19:

Species:	**Coastal Wetern Hemlock**
Average Volume per Stem:	**very low**
Average Stem Form:	**good**
Incidence of Defects:	**high**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**low**
Mean Wood Density:	**high**
Within-stem Density Variability:	**high**
Between-stem Characteristic Variability:	**low**
Total Delivered Fibre Cost:	**very low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

#20:

Species:	**Coastal Western Red Cedar**
Average Volume per Stem:	**low**
Average Stem Form:	**poor**
Incidence of Defects:	**low**
Incidence of Clearwood:	**no merchantable length of stem clear of knots**
Incidence of Juvenile Wood:	**high**
Mean Wood Density:	**high**
Within-stem Density Variability:	**low**
Between-stem Characteristic Variability:	**high**
Total Delivered Fibre Cost:	**low**

0 1 2 3 4 5 6 7 8 9 10

very low value — very high value (circle one number)

Comments (optional):

****

Please check to ensure that you have completed all questions before returning this survey in the envelope provided. If you would like me to send you a copy of the results of analyzing the survey responses please check the following blank: Yes [_____]

Thanks again for taking the time to participate in this research.

****

****

THE END

****

tear here

CHART OF WOOD CHARACTERISTICS AND THEIR LEVELS

In Section 4 of this survey four different species of timber (Coastal Douglas-fir, Coastal Western Red Cedar, Coastal Western Hemlock and Coastal Balsam) are described in terms of nine characteristics or properties. These characteristics and the levels at which they appear in wood descriptions are defined in this chart. Please tear this page out, familiarize yourself with the definitions and refer to the chart when answering the questions in Section 4.

LEVELS AT WHICH CHARACTERISTICS DEFINED

CHARACTERISTICS				
Average Volume per Stem:	**very low** (0-1m^3)	**low** (1-2m^3)	**high** (2-3m^3)	**very high** (3-4m^3)
Average Stem Form:	**poor** (substantial twist, lean, taper or sweep)	**good** (minor or no twist lean, taper or sweep)		
Incidence of Defects:	**low** (eg., 10% stem volume effected by conk, stain, fork, check, insect holes etc.)	**high** (eg., 30% stem volume effected by conk, stain, fork, check, insect holes etc.)		
Incidence of Clearwood:	**no merchantable length of stem clear of knots**	**at least one merchantable length of stem clear of knots**		
Incidence of Juvenile Wood:	**low** (eg., 20% stem volume)	**high** (eg., 50% stem volume)		
Mean Wood Density:	**low** (equal to lower bound of current provincial mean stem density range for species)	**high** (equal to upper bound of current provincial mean stem density range for species)		
Within-stem Density Variabiltiy:	**low** (equal to lower bound of range of current provincial within-stem density variability for species)	**high** (equal to upper bound of range of current provincial within-stem density variability for species)		
Between-stem Characteristic Variability:	**low** (no range greater than 20% of average value)	**high** (characteristic ranges greater than 20% of average value)		
Total Delivered Fibre Cost: (current CAN$/BDMT)	**very low** (eg., $50/BDMT)	**low** (eg., $100/BDMT)	**high** (eg., $150/BDMT)	**very high** (eg. $200/BDMT)

Department of Rural Economy
University of Alberta, Edmonton

Dear

By now you will have received a copy of my survey dealing with the future wood quality requirements of British Columbia's Coastal forest product industry. This research is part of my doctoral thesis in Forest Economics and has been discussed with, and is supported by, the Forest Economics Policy Analysis unit (FEPA) and the Council of Forest Industries (COFI).

If you have already completed the survey and returned it to me I would like to thank you for participating in this research. If you have not yet responded to my survey I hope you decide to participate by completing the questionnaire and returning it to me in the envelope provided by February 19th, 1990. Wood quality is now widely recognised as an important forest management and planning issue, and my research offers you a way to express your opinions on this subject.

I assure you that your responses to my survey are confidential, but I can make the aggregate results of the study available to you. If you have any questions or have misplaced your copy of the survey please contact me at (403) 492 5002. I look forward to receiving your completed questionnaire.

Sincerely yours,

Sarah Jennings

COASTAL BRITISH COLUMBIA - FUTURE WOOD QUALITY SURVEY

Department of Rural Economy
University of Alberta, Edmonton

Dear

By now you will have received a copy of my survey dealing with the future wood quality requirements of British Columbia's Coastal forest product industry. This research is part of my doctoral thesis in Forest Economics and has been discussed with, and is supported by, the Forest Economics Policy Analysis unit (FEPA) and the Council of Forest Industries (COFI).

If you have already completed the survey and returned it to me I would like to thank you for participating in this research. If you have not yet responded to my survey I hope you decide to participate by completing the questionnaire and returning it to me in the envelope provided by February 19th, 1990. Wood quality is now widely recognised as an important forest management and planning issue, and my research offers you a way to express your opinions on this subject.

I assure you that your responses to my survey are confidential, but I can make the aggregate results of the study available to you. If you have any questions or have misplaced your copy of the survey please contact me at (403) 492 5002. I look forward to receiving your completed questionnaire.

Sincerely yours,

Sarah Jennings

COASTAL BRITISH COLUMBIA - FUTURE WOOD QUALITY SURVEY

Appendix II: Experimental Designs

(i) Section 2 - 2^n Main Effects Plans

(ii) Section 4 - Modified Hadamard Design of Order 20

(i) Section 2 - 2^n Main Effects Plans (Resolution III Designs)

n = 4

```
+ + + +
+ + - -
+ - + -
+ - - +
```

n = 12

```
+ + + + + + + + + + + +
+ + - + + + - - - + - -
+ - + - + + + - - - + -
+ - - + - + + + - - - +
+ + - - + - + + + - - -
+ - + - - + - + + + - -
+ - - + - - + - + + + -
+ - - - + - - + - + + +
+ + - - - + - - + - + +
+ + + - - - + - - + - +
+ + + + - - - + - - + -
+ - + + + - - - + - - +
```

(ii) Section 4 – Modified Hadamard Design of Order 20[a].

3	3	3	1	1	1	1	1	1	1
1	3	3	1	0	1	0	1	1	0
2	0	3	1	1	0	1	0	0	1
0	1	2	1	1	1	0	1	0	1
1	2	2	1	1	1	1	0	0	0
3	0	1	0	1	1	1	1	0	0
2	1	2	0	0	1	1	1	1	0
0	3	0	1	0	0	1	1	0	0
0	2	1	0	1	0	0	1	1	1
0	0	3	0	0	1	0	0	0	0
1	0	2	1	0	0	1	0	1	1
2	0	0	1	1	0	0	1	1	0
1	1	0	0	1	1	0	0	1	1
2	2	0	0	0	1	1	0	1	1
1	1	1	0	0	0	1	1	0	1
3	2	0	0	0	0	0	1	0	1
3	1	1	1	0	0	0	0	1	0
3	3	2	0	1	0	0	0	0	0
2	3	1	1	0	1	0	0	0	1
0	2	3	0	1	0	1	0	1	0

a. Design constructed by Dr. Donald A. Anderson, University of Wyoming for main-effects only experiment with three four-level and seven two-level characteristics.

Appendix III: Estimated Hedonic Price Equation for Sterling Wood Group Inc. (1988) Regrowth Price Matrix

Variable[a]	Coefficient	t-statistic[b]
spruce	7.67	4.56*
hemlock	8.69	5.16*
cedar	-4.93	-2.93*
balsam	8.98	5.34*
tree height (th)	0.67	4.57*
dbh	1.96	21.92*
$(th)^2$	-0.00	-3.22*
$(dbh)^2$	-0.01	-15.0*
(th)(dbh)	-0.00	22.79*
(th)(spruce)	-0.03	-0.84
(th)(hemlock)	-0.01	-0.40
(th)(cedar)	0.08	2.05
(th)(balsam)	-0.04	-0.99
(dbh)(spruce)	-0.24	-7.98*
(dbh)(hemlock)	-0.22	-7.35*
(dbh)(cedar)	0.26	8.70*
(dbh)(balsam)	-0.30	-10.2*
constant	-20.2	-6.87*

R^2 - 0.97
Number of Observations - 175
F(18,157) = 350.13 P-value = 0.0

a. Douglas-fir is the excluded species dummy
b. An * denotes variables which are significant at the 95 percent level.